URBAN STORMWATER IMPACTS; STRUCTURAL CONTROL STRATEGIES AND EROSION PREVENTION/SEDIMENT CONTROL

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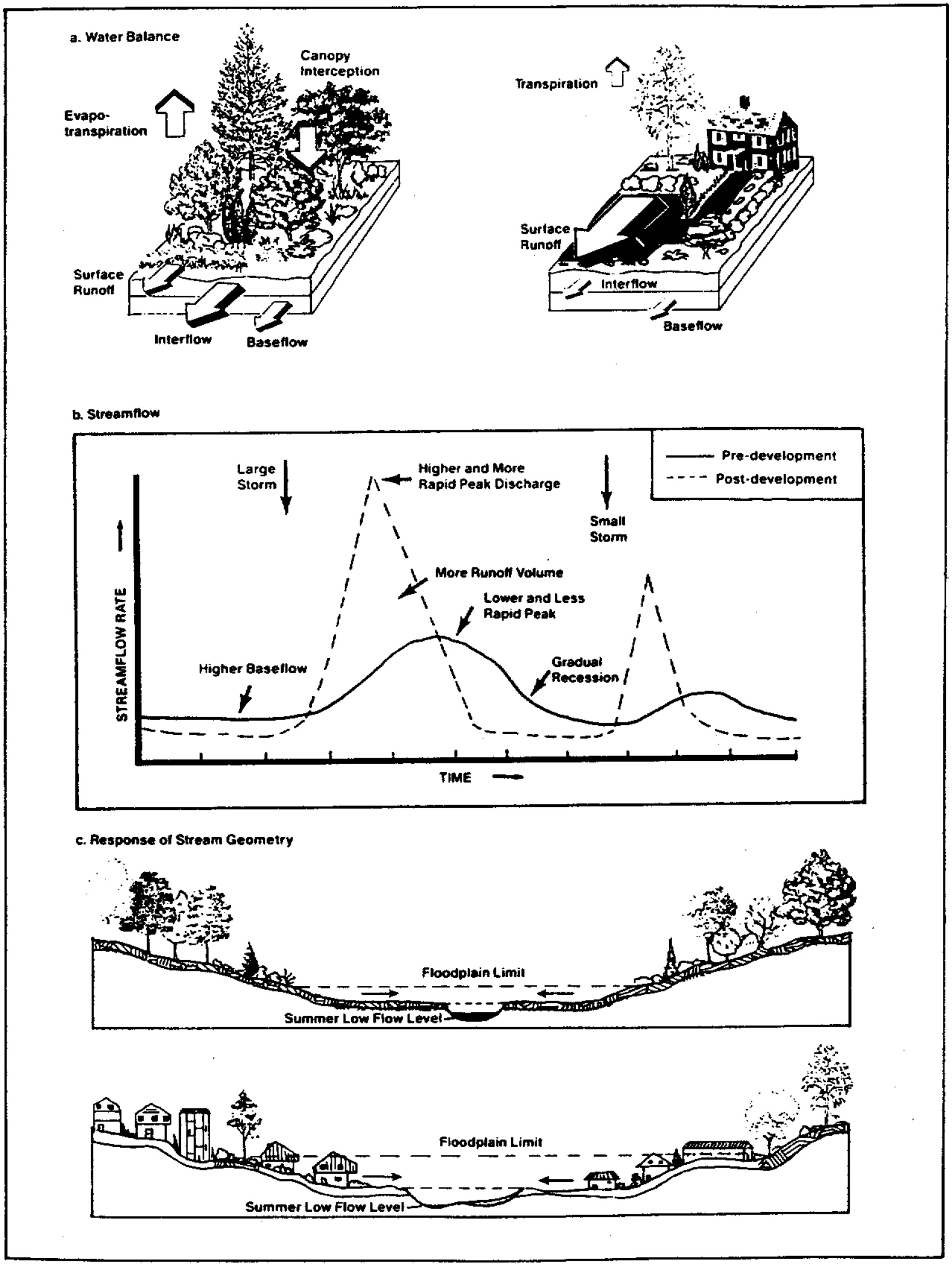
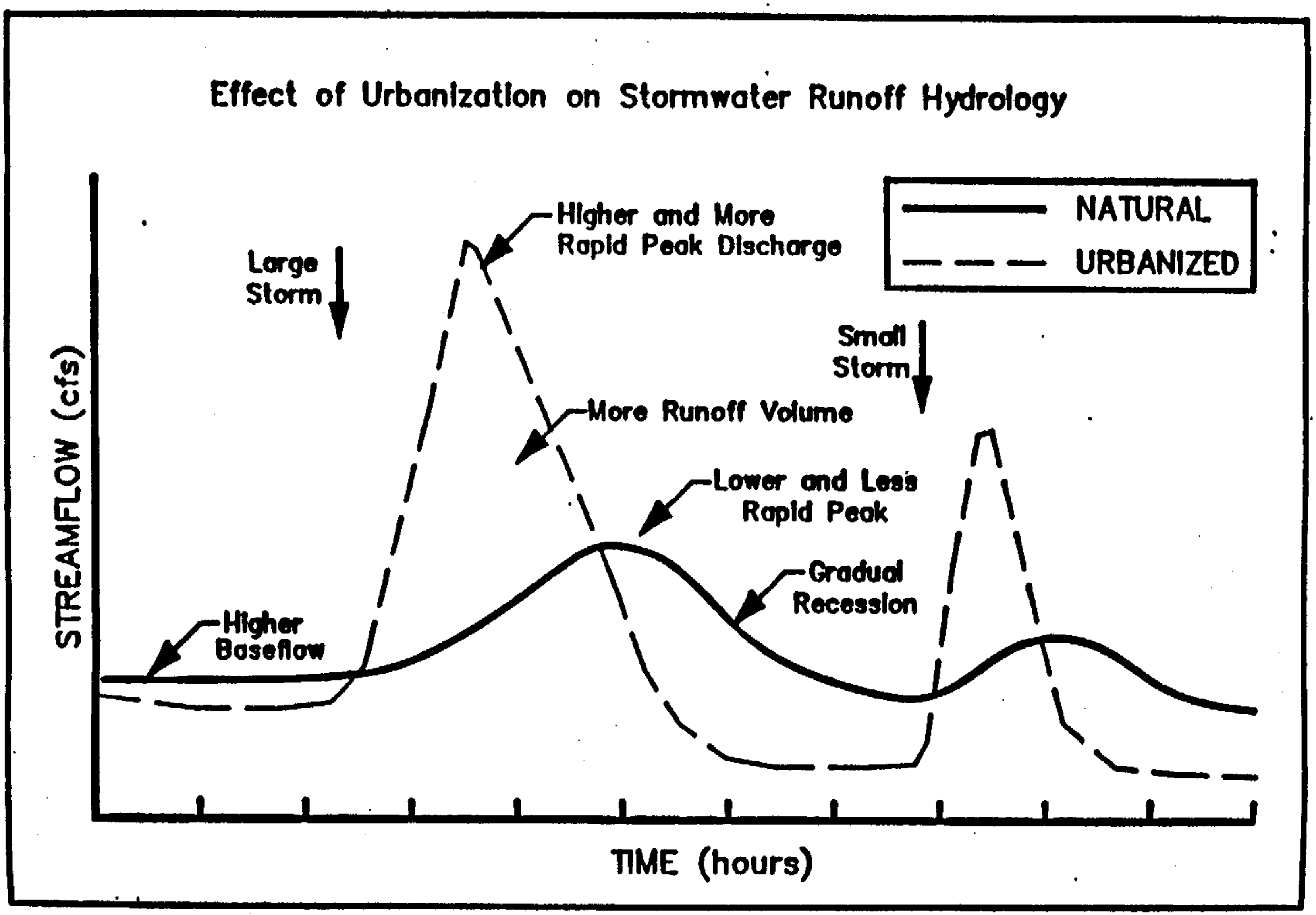
URBAN STORMWATER IMPACTS

Figure 1.1: Changes in Watershed Hydrology as a Result of Urbanization



"WASHCOG, 1987"



After Schueler, MWCOG, 1987

CHARACTERISTICS OF URBAN DISCHARGES

- Nonpoint Sources
  - Intermittent
  - Pulse nature
  - Large fluctuations in flow
  - Wide variation of quality
  - Dispersed locations

- Point Sources
  - Consistent
  - Continuous input
  - Relatively small fluctuations in flow
  - Low variation of quality
  - Discrete location

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URBAN RUNOFF VERSUS TYPICAL DOMESTIC WASTEWATER

(Raw and Secondary Treatment)

Source: USEPA NURP FINAL REPORT

(All Values in mg/l)

CONSTITUENT	URBAN RUNOFF TYPICAL (MEAN) CONCENTRATION	RAW WASTEWATER CONCENTRATION	2ND SEWAGE EFFLUENT CONCENTRATION
COD	75	500	80
TSS	150	220	20
TOTAL P	0.36	8	2
TOTAL N	2	40	30
LEAD	0.18	0.10	0.05
COPPER	0.05	0.22	0.03
ZINC	0.20	0.28	0.08
FECAL COLIFORM (GS/100 MIL)	UP TO 50×10^3	UP TO 1×10^8	200

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REPRESENTATIVE RATES OF EROSION FROM VARIOUS LAND USES*

LAND USE	EROSION RATE TONS/MI^2-YR	RELATIVE TO FOREST = 1
FOREST	24	1
GRASSLAND	240	10
ABANDONED SURFACE MINES	2,400	100
CROPLAND	4,800	200
HARVESTED FOREST	12,000	500
ACTIVE SURFACE MINES	48,000	2,000
CONSTRUCTION	48,000	2,000

*Canter, Larry Environmental Impact Assessment, McGraw Hill, 1977

C. The First Flush

Of primary importance to minimizing the effects of stormwater on water quality is the **FIRST FLUSH** *(Figure 5)*. This term describes the washing action that stormwater has on accumulated pollutants in a watershed. In the early stages of runoff the land surfaces, especially the impervious surfaces like streets and parking areas, are flushed clean by the stormwater. This creates a shock loading of pollutants. Studies in Florida have determined that the first one inch of runoff generally carries 90% of the pollution from a storm.

Treatment of the first flush is the key to proper stormwater management, and treatment of the first one inch of runoff from new development is the minimum needed to achieve the desired water quality benefits. In some cases, more than the first inch may need treatment-depending on the size of the drainage basin, the amount of impervious surface, the type of land use, the type of stormwater management system and, most importantly, the type of receiving water and the desired water quality.

Figure 5

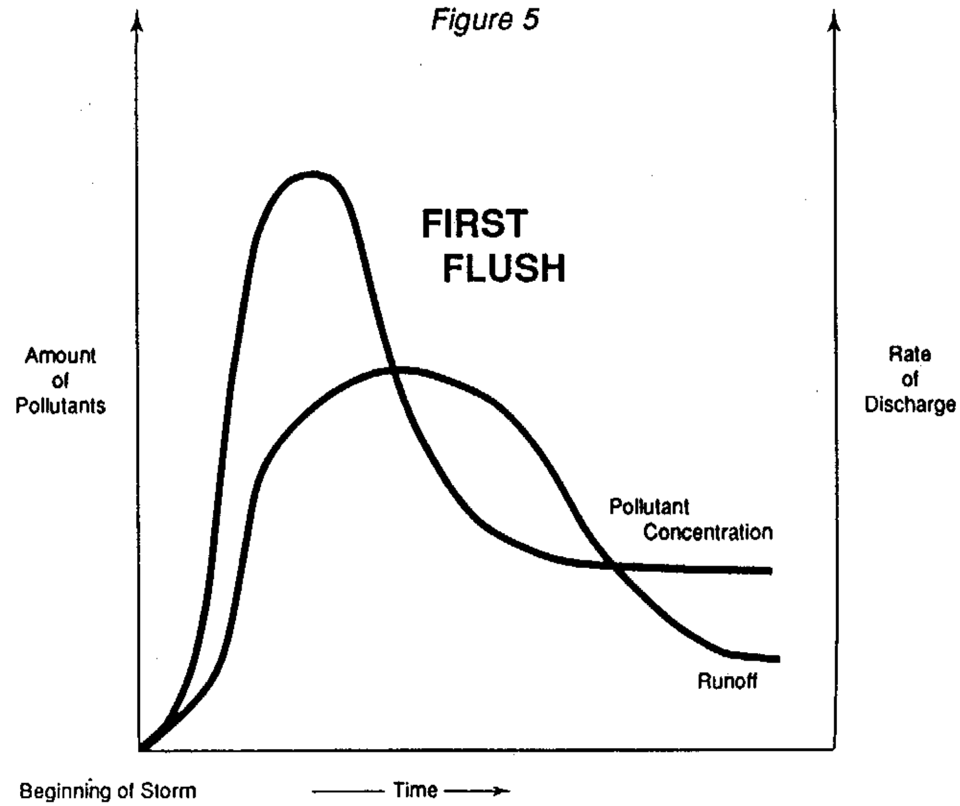


Table 1: Major Stream Impacts Caused by Urbanization

Changes in Urban Stream Hydrology

Increase in Magnitude and Frequency of Severe Floods
Increased Frequency of Erosive Bankfull Floods
Increase in Annual Volume of Surface Runoff
More Rapid Stream Velocities
Decrease in Dry-Weather Baseflow on Stream

Changes in Urban Stream Morphology

Stream Channel Widening and Downcutting
Increased Streambank Erosion
Shifting Bars of Coarse-Grained Sediments
Elimination of Pool/Riffle Structure
Imbedding of Stream Sediments
Stream Relocation/Enclosure or Channelization
Stream Crossings Form Fish Barriers

Changes in Urban Stream Water Quality

Massive Pulse of Sediment During Construction Stage
Increased Washoff of Pollutants
Nutrient Enrichment Leads to Benthic Algal Growth
Bacterial Contamination During Dry and Wet Weather
Increase in Organic Carbon Loads
Higher Levels of Toxics, Trace Metals and Hydrocarbons
Water Temperature Enhancement
Trash/Debris Jams

Changes in Stream Habitat and Ecology

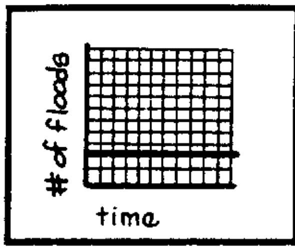
Shift from External to Internal Stream Production
Reduction in Diversity of Aquatic Insects
Reduction in Diversity and Abundance of Fish
Destruction of Wetlands, Riparian Buffers, and Springs

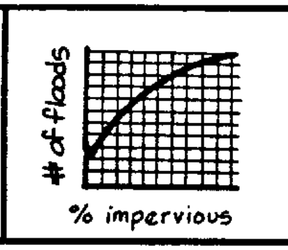
Reference: Schueler, Thomas R. "Mitigating the Adverse Impacts of Urbanization on Streams: A Comprehensive Strategy for Local Government"

Anacostia: A Watershed Transformed

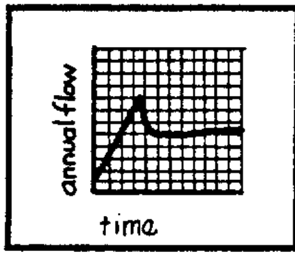
IMPACTS OF URBANIZATION

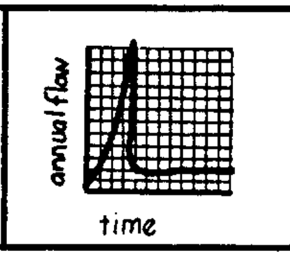
Before | **After**



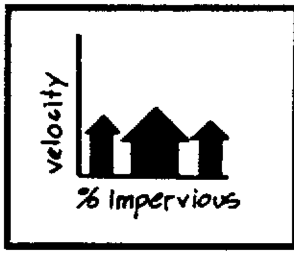


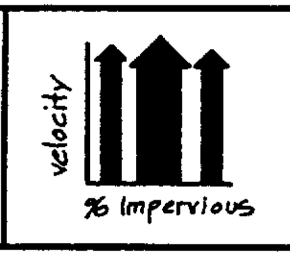
INCREASED BANKFULL FLOODING
The frequency of bankfull floods increases from once every other year prior to development, to over 5 each year for a 50% impervious watershed. In the Anacostia, short but intense summer storms turn stream channels into raging torrents, causing severe channel scour and erosion.



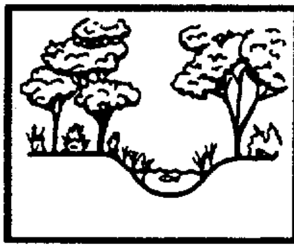


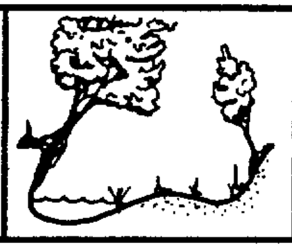
LOWER DRY WEATHER FLOW
Reduced dry weather flows may cause small perennial urban streams to become seasonally dry, while significantly reducing the wetted perimeter of larger urban streams, thus reducing aquatic habitat area. In much of the Anacostia, seasonally reduced discharges significantly restrict the availability of fish and aquatic habitat.



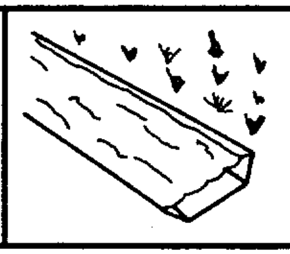


INCREASED STREAM VELOCITY
Greater amounts of stormwater discharge in concert with rapid concentration times over smooth, paved surfaces produce increases in stream velocity. In portions of the Anacostia, this increased channel velocity has caused severe erosion and destruction of both aquatic and riparian habitat.

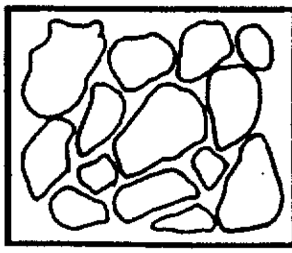


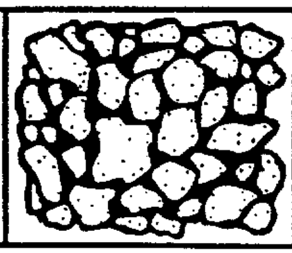


CHANNEL WIDENING
Increased stormflow velocity in urban streams severely erodes the adjacent stream banks, resulting in a loss of riparian habitat and forest cover. In portions of the developed Anacostia, channels have become two to eoght times wider than in undeveloped zones.



LOSS OF POOLS & RIFFLES
Pools and riffles provide habitat diversity for the aquatic community. Stream channel erosion and construction site runoff create significant changes in stream morphology. In portions of the Anacostia, this change has eliminated many pools and riffles that support fish habitat.





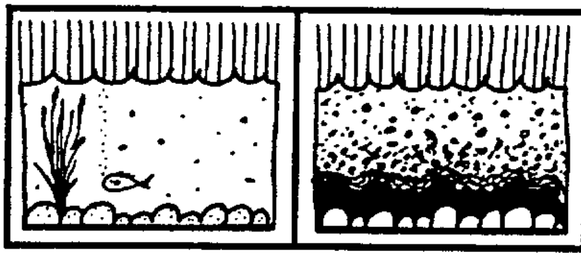
CHANGE IN SUBSTRATE QUALITY
With urbanization comes a shift in the grain size of channel sediments, from coarser grained particles, to a mixture of fine and coarse particles. This results in a phenomena known as embedding: sand, silt, and clay fill voids in the channel bottom, reducing water circulation, oxygen, and organic matter needed by aquatic insects.

(Washington, D.C. COG, 1990)

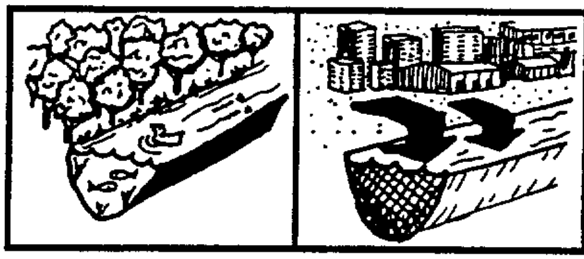
Anacostia: A Watershed Transformed

Before **After**

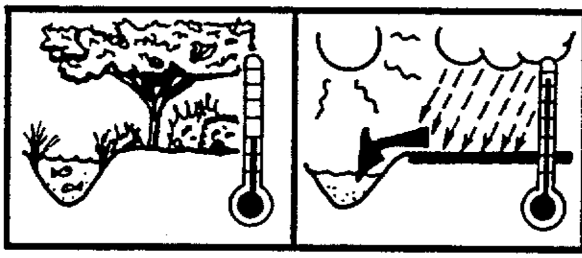
IMPACTS OF URBANIZATION



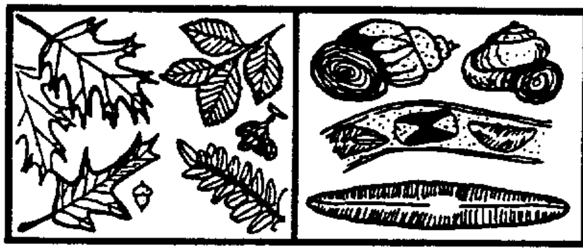
CONSTRUCTION SEDIMENT PULSE
During the initial phase of development, an urban stream receives a massive pulse of sediment that has eroded from upland construction sites. In the Anacostia, sediment levels often decline once upland development is stabilized, yet never return to pre-development levels, because of increased streambank erosion.



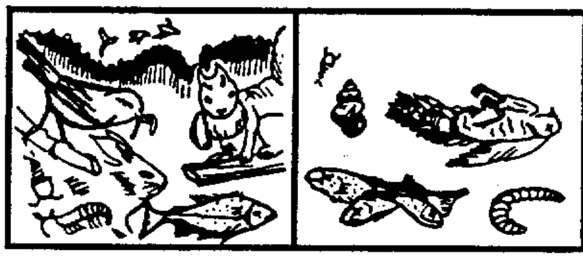
INCREASED POLLUTANT LEVELS
Pollutant levels in urban streams can often be one to two orders of magnitude greater than a forested watershed. In the Anacostia, pollutant wash-off from impervious areas include: nitrogen, phosphorus, carbon, solids, fecal material, herbicides, pesticides, and trace metals, and oil and grease.



INCREASED WATER TEMPERATURE
Impervious areas function as heat sinks. This heat is transferred to stormwater runoff. Intensive urbanization can raise stream water temperatures by 5 to 10 degrees celsius. In the Anacostia, this thermal loading severely interferes with the physiological requirements of coldwater aquatic organisms such as trout and stoneflies creating stress and environmentally uninhabitable conditions.



SHIFT IN ENERGY SOURCE
In a natural stream, the aquatic community is driven by an energy source made up of decomposing leaves and woody debris. In urban streams, reduced tree canopy in combination with nutrient accumulation results in increased benthic algal production. This change manifests itself in a dramatic shift of species in the stream.



REDUCTION OF COMMUNITY DIVERSITY
In intensively developed areas, urban streams support only a fraction of the fish and aquatic insects that exist in undeveloped watersheds. This loss of biological diversity leaves the natural community vulnerable to changes in climate and habitat.

LOSS OF FRESHWATER WETLAND BUFFERS
A stream ecosystem is dependant upon its extensive freshwater wetlands, floodplains, riparian buffers, seeps, springs, and ephermal channels. Historically in the Anacostia, these associated areas were frequently destroyed or altered by agriculture and urban development.

(Washington, D.C. COG, 1990)

OVERVIEW OF STORMWATER QUALITY MANAGEMENT

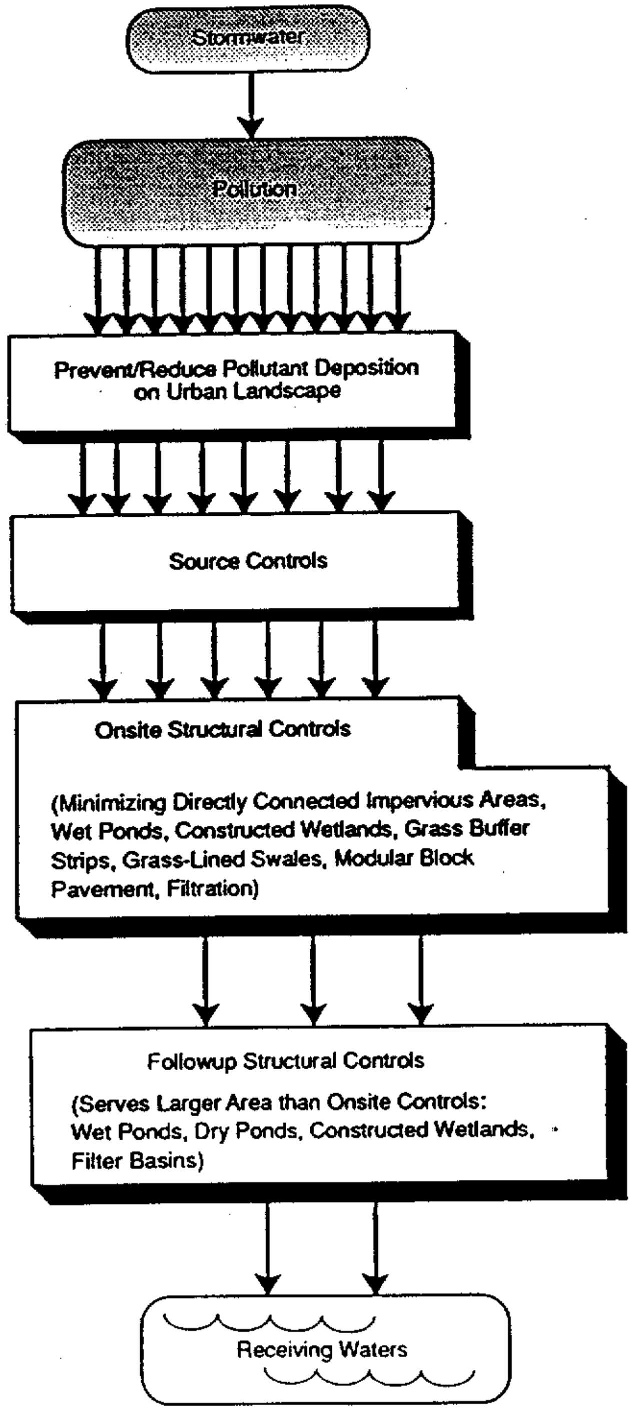


FIGURE 2-2. MULTI-LEVEL STORMWATER QUALITY MANAGEMENT STRATEGY

BEST MANAGEMENT PRACTICES

~ SUMMARY ~

- DESIGN RUNOFF QUALITY CONTROLS TO CAPTURE SMALL STORMS
- DESIGN TO MAXIMIZE SEDIMENT REMOVAL, AND REMOVAL OF OTHER POLLUTANTS WILL GENERALLY BE GOOD
- THE MOST EFFECTIVE METHOD FOR REDUCING URBAN RUNOFF POLLUTION IS TO MINIMIZE DIRECTLY CONNECTED IMPERVIOUS AREA (DCIA)
- OFF-LINE DEVICES ARE MORE EFFECTIVE THAN ON-LINE DEVICES
- INFILTRATION DEVICES ARE MOST EFFICIENT BUT MOST DIFFICULT TO MAINTAIN
- DRY DETENTION IS EASIEST TO DESIGN AND OPERATE, BUT EFFICIENCY CAN BE LOW, ESPECIALLY IF IT IS ON LINE
- WET DETENTION IS MORE DIFFICULT TO DESIGN BUT MORE EFFICIENT THAN WET DETENTION, AND OFTEN MORE AESTHETIC
- WITH SOME THOUGHT, URBAN RUNOFF QUALITY CONTROLS CAN BE AESTHETICALLY INTEGRATED INTO DEVELOPMENT PLANS

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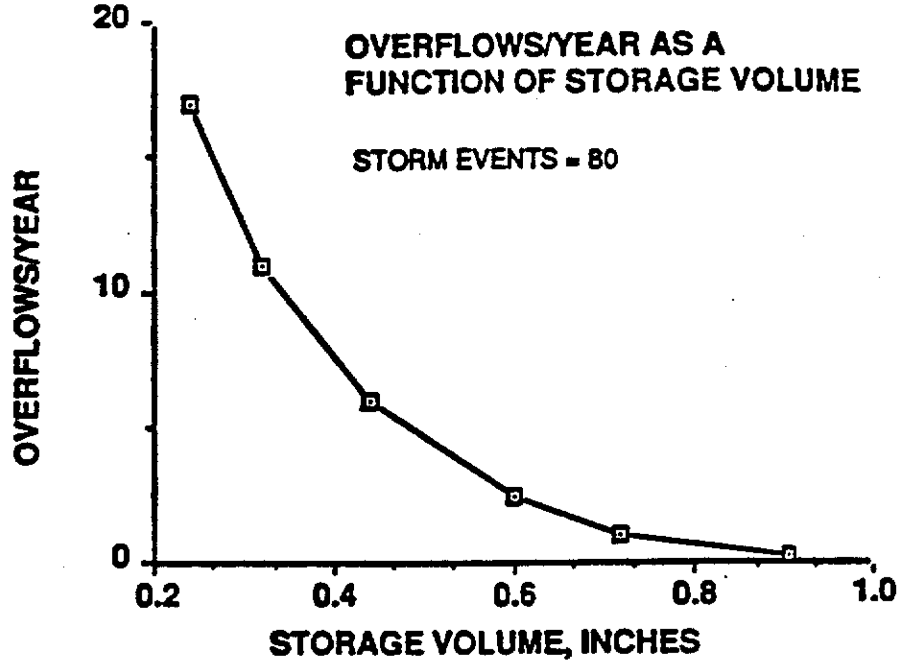

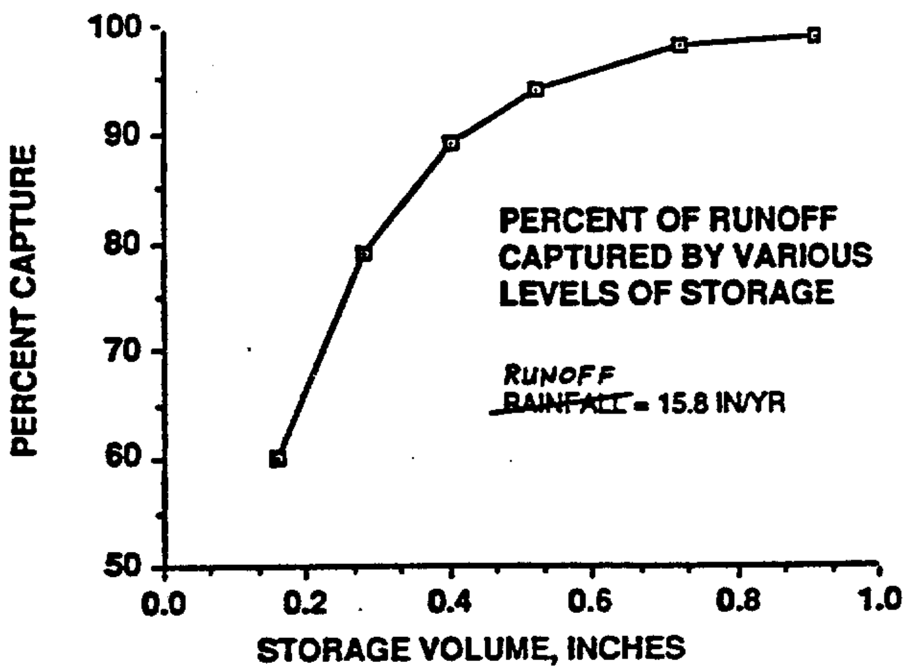

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B. On-Line Versus Off-Line BMPs

On-line BMPs temporarily store runoff before they discharge to surface waters. These systems capture all of the runoff from a design storm. They primarily provide flood control benefits. Water quality benefits are secondary.

Off-line BMPs divert the first flush of polluted stormwater for treatment and isolate it from the remaining stormwater, which is managed for flood control. Off-line retention is the most effective water quality protection BMP, since the diverted first flush is not discharged to surface waters but is stored-to be gradually removed by infiltration, evaporation and evapotranspiration.

Figure 9 is a schematic of an off-line treatment system in which a **smart weir** directs the first flush of stormwater into the infiltration area until it is filled. The remaining runoff is routed to the detention facility for flood control.

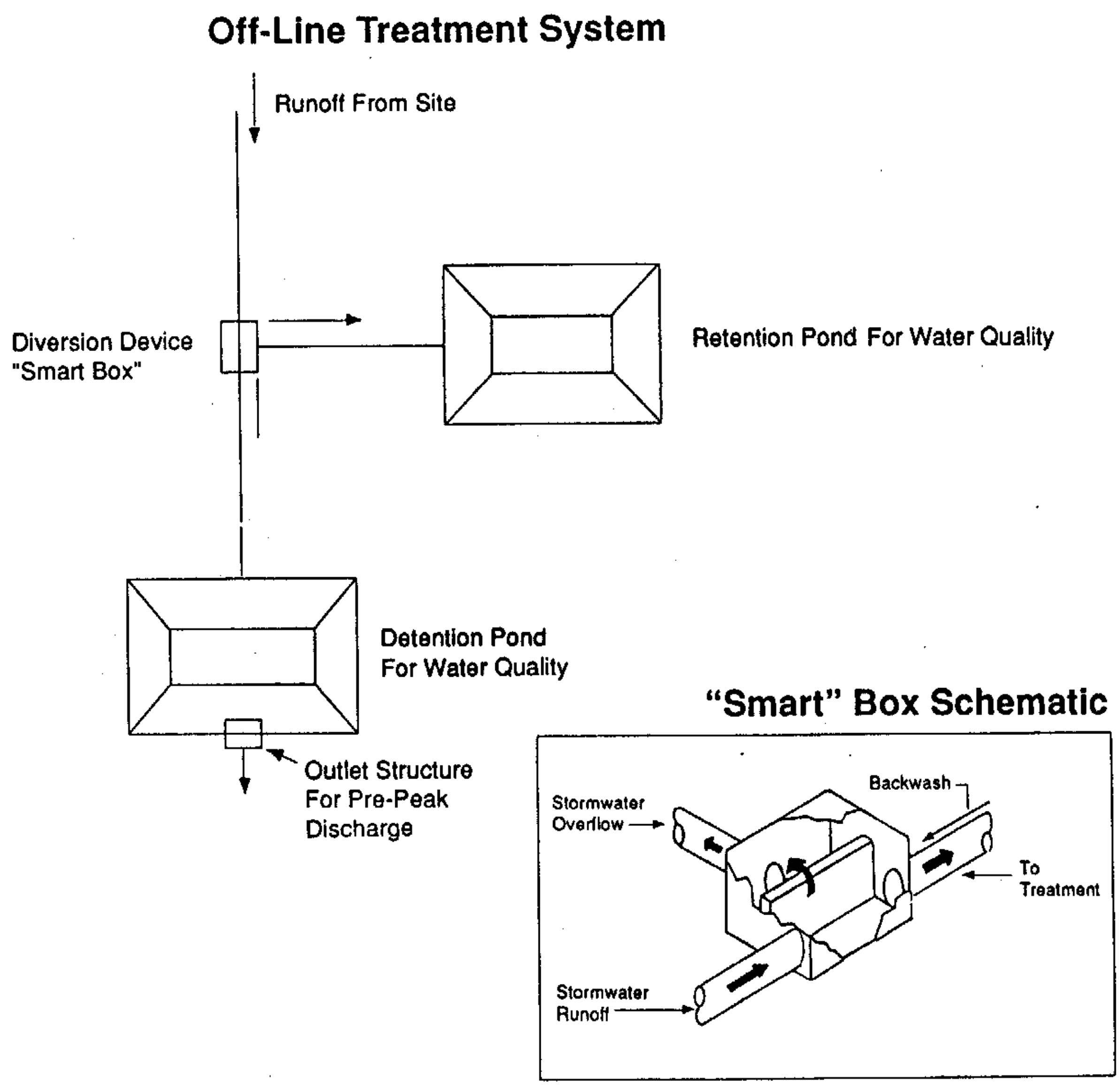


Figure 9: **SCHEMATIC OF "DUAL-POND" OFF-LINE TREATMENT SYSTEM**

Florida Department of Environmental Regulation, 1994

- **Infiltration practices**
  - Basins
  - Trenches
  - Perforated pipes
  - French drains
  - Porous pavements
- **Filtration practices**
  - Sand filters
  - Leaf compost filters
  - Catch basin filters (various media)

The ponds, vaults, and tanks under storage practices can benefit quantity control, quality control, or both. However, dry ponds drain too quickly to provide any substantial runoff treatment. Enclosed vaults and tanks are limited in biological activity and are usually too small to function well in water quality control. Therefore, these devices are only effective for quantity control. Wetlands and all infiltration options can also supply quantity and quality control. The remaining practices are largely treatment devices.

In a number of instances, one mode of operation (storage, vegetative treatment, or infiltration) predominates but the practice incorporates other modes. For example, wetlands involve both storage of water and vegetative action. Also, most ponds infiltrate some water unless they are lined.

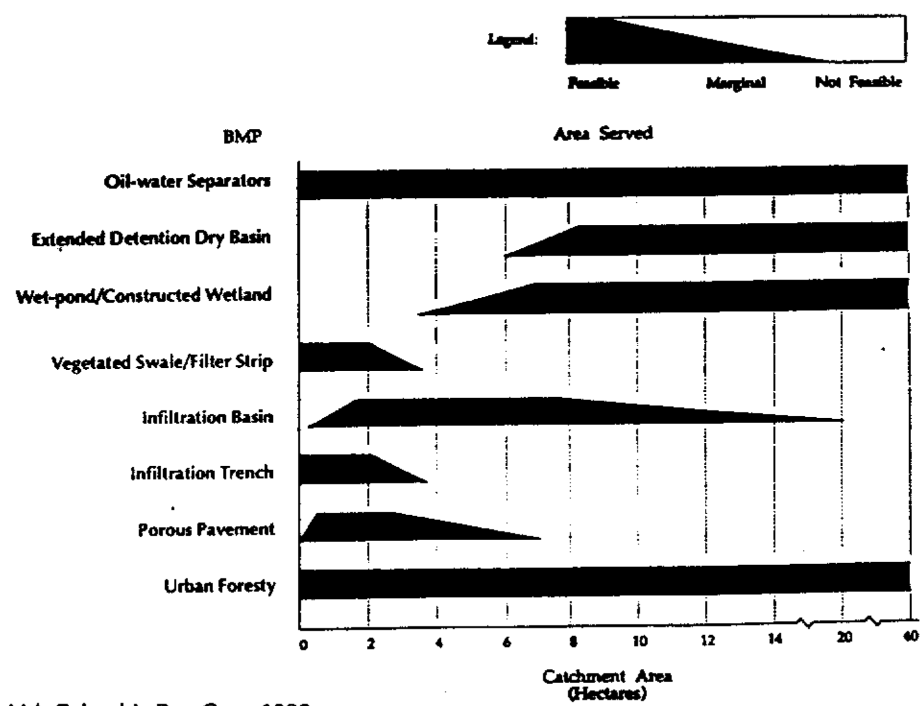
The trend is to combine the capabilities of two or more options by establishing "treatment trains" arranged in series, a strategy discussed at the end of this chapter.

Practice Selection

Success in applying any management practice initially depends on selecting the appropriate option for the site's control objectives and conditions. The objectives must be clearly delineated at the outset and conditions investigated in enough detail to match the practice to the site. Objectives might include whether quantity control, quality control, or both are to be provided; what pollutants are to be treated; and what, if any, side benefits are to be produced. Conditions that determine a practice's relevance include service area, soils, hydrogeologic conditions, and circumstances of the receiving water and nearby properties.

The British Columbia Research Corporation (1992) developed charts that incorporate these considerations, adapting and extending earlier work by Schueler (1987) and the Washington Department of Ecology (1992). Figures 8.1 and 8.2 and Tables 8.1 through 8.4 present these charts as aids in practice screening.

Figure 8.1—Applicability of treatment practices relative to catchment area.



Source: British Columbia Res. Corp. 1992.

"Horner et. al., 1994"

Table 8.2—Comparative quantity control benefits provided by water quality control practices.

BMP	PEAK DISCHARGE CONTROL			VOLUME CONTROL	GROUNDWATER RECHARGE/LOW FLOW MAINTENANCE	STREAMBANK EROSION CONTROL
	2-YEAR STORM	10-YEAR STORM	100-YEAR STORM			
Oil-water separator	○	○	○	○	○	○
Extended detention dry basin	●	●	●	○	○	●
Wet pond	●	●	●	○	○	●
Constructed wetland	●	●	●	■	■	●
Vegetated swale / Filter strip / Urban forestry	■	○	○	■	■	○
Full infiltration basin	●	■	○	●	●	●
Combined infiltration-detention basin	●	●	●	●	●	●
Off-line infiltration basin	○	○	○	●	●	●
Full infiltration trench / Porous pavement	●	■	○	●	●	●

● Usually provided.
■ Sometimes provided with careful design.
○ Seldom or never provided.

Source: British Columbia Res. Corp. 1992.

Table 8.3—Potential pollutant removal effectiveness of treatment practices.

BMP	CONTAMINANT						
	SUSPENDED SOLIDS	OXYGEN DEMAND	TOTAL LEAD	TOTAL ZINC	TOTAL PHOSPHORUS	TOTAL NITROGEN	BACTERIA
Oil-water separator	○	◆	◆	◆	◆	◆	◆
Extended detention dry basin	●	■	●	■	■	○	◆
Wet pond	●	■*	●	■	■*	○*	◆
Constructed wetland	●	●*	●	●	●*	●*	◆
Vegetated swale	●	○	●	■	○	○	◆
6 meter-wide turf filter strip	○	○	○	○	○	○	◆
30 meter-wide forested filter strip	●	●	●	●	■	■	◆
Infiltration practices	●	●	●	●	●	■	●

● High potential for removal.
■ Moderate potential for removal.
○ Low potential for removal.
◆ Insufficient knowledge.
* May be subject to exports of nutrient-enriched and deoxygenated water.

Source: British Columbia Res. Corp. 1992.

"Horner et. al., 1994"

urban runoff and the factors that promote the operation of each mechanism to improve water quality.

A factor to consider in the functioning of all mechanisms is time. The effectiveness of settling a solid particle is directly related to the time provided to complete sedimentation at the particle's characteristic settling velocity. Time is also a crucial variable to determine the degree that chemical and biological mechanisms operate. Characteristic rates of chemical reactions and biologically mediated processes must be recognized to obtain treatment benefits. For all of these reasons, water residence time is the most basic variable to apply effective treatment practice technology.

The information in Table 8.5 can also be arranged by features that promote specific pollutant control objectives. The following features fulfill the most common objectives:

- **Features that help achieve any objective**
  - Increasing hydraulic residence time
  - Low turbulence
  - Fine, dense herbaceous plants
  - Medium-fine textured soil

- **Features that help achieve specific objectives**
  - Phosphorus control
    - High soil exchangeable aluminum and/or iron content
    - Addition of precipitating agents
  - Nitrogen control
    - Alternating aerobic and anaerobic conditions
    - Low toxicants
    - Circumneutral pH

- **Metals control**
  - High soil organic content

Table 8.5—Summary of pollutant removal mechanisms.

MECHANISM	POLLUTANTS AFFECTED	PROMOTED BY
Physical sedimentation	Solids, BOD, pathogens; particulate COD, P, N, metals, synthetic organics	Low turbulence
Filtration	Same as sedimentation	Fine, dense herbaceous plants; constructed filters
Soil incorporation	All	Medium-fine texture
Chemical precipitation	Dissolved P, metals	High alkalinity
Adsorption	Dissolved P, metals, synthetic organics	High soil Al, Fe high soil organics (met.); circumneutral pH
Ion exchange	Dissolved metals	High soil cation exchange capacity
Oxidation	COD, petroleum hydrocarbons, synthetic organics	Aerobic conditions
Photolysis	Same as oxidation	High light
Volatilization	Volatile petroleum hydrocarbons and synthetic organics	High temperature and air movement
Biological microbial decomposition	BOD, COD, petroleum hydrocarbons, synthetic organics	High plant surface area and soil organics
Plant uptake and metabolism	P, N, metals	High plant activity and surface area
Natural die-off	Pathogens	Plant excretions
Nitrification	NH_3-N	Dissolved oxygen > 2 mg/L, low toxicants, temperature > 5-7°C, circumneutral pH
Denitrification	NO_3+NO_2-N	Anaerobic, low toxicants, temperature > 15°C

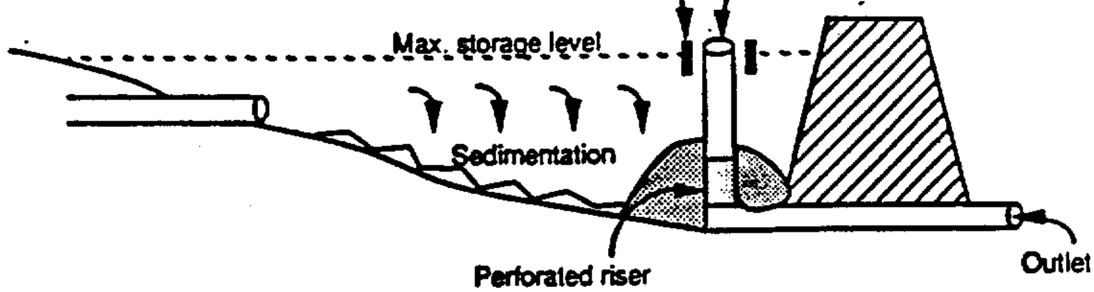
Source: R.R. Horner.

"Horner et. al., 1994"

STORMWATER QUALITY BMPs

- Dry Ponds
- Wet Ponds
- Infiltration Devices
- Swales and Filter Strips
- Wetlands
- Porous Pavement
- Sand Filters/Special Inlets
- Public Education

DRY DETENTION PONDS



- EFFICIENCY: POOR FOR DETENTION TIMES UNDER 12 HRS.

  GOOD FOR DETENTION TIMES GREATER THAN 24 HOURS

- FUNCTION: SETTLE POLLUTANTS OUT; SOLUBLE POLLUTANTS PASS THROUGH

- MAINTENANCE IS MODERATE IF PROPERLY DESIGNED

- IMPROPER DESIGN CAN MAKE FACILITIES AN EYESORE AND A MOSQUITO-BREEDING MUDHOLE

- NEWER DESIGNS ARE INCORPORATING A SHALLOW MARSH AROUND OUTLET. RESULT: BETTER REMOVAL EFFICIENCY AND NO MOSQUITO NUISANCE

- REGIONAL DETENTION FACILITIES SERVING 100 - 200 ACRES CAN BE AESTHETICALLY DEVELOPED RESULT: LOWER MAINTENANCE COSTS

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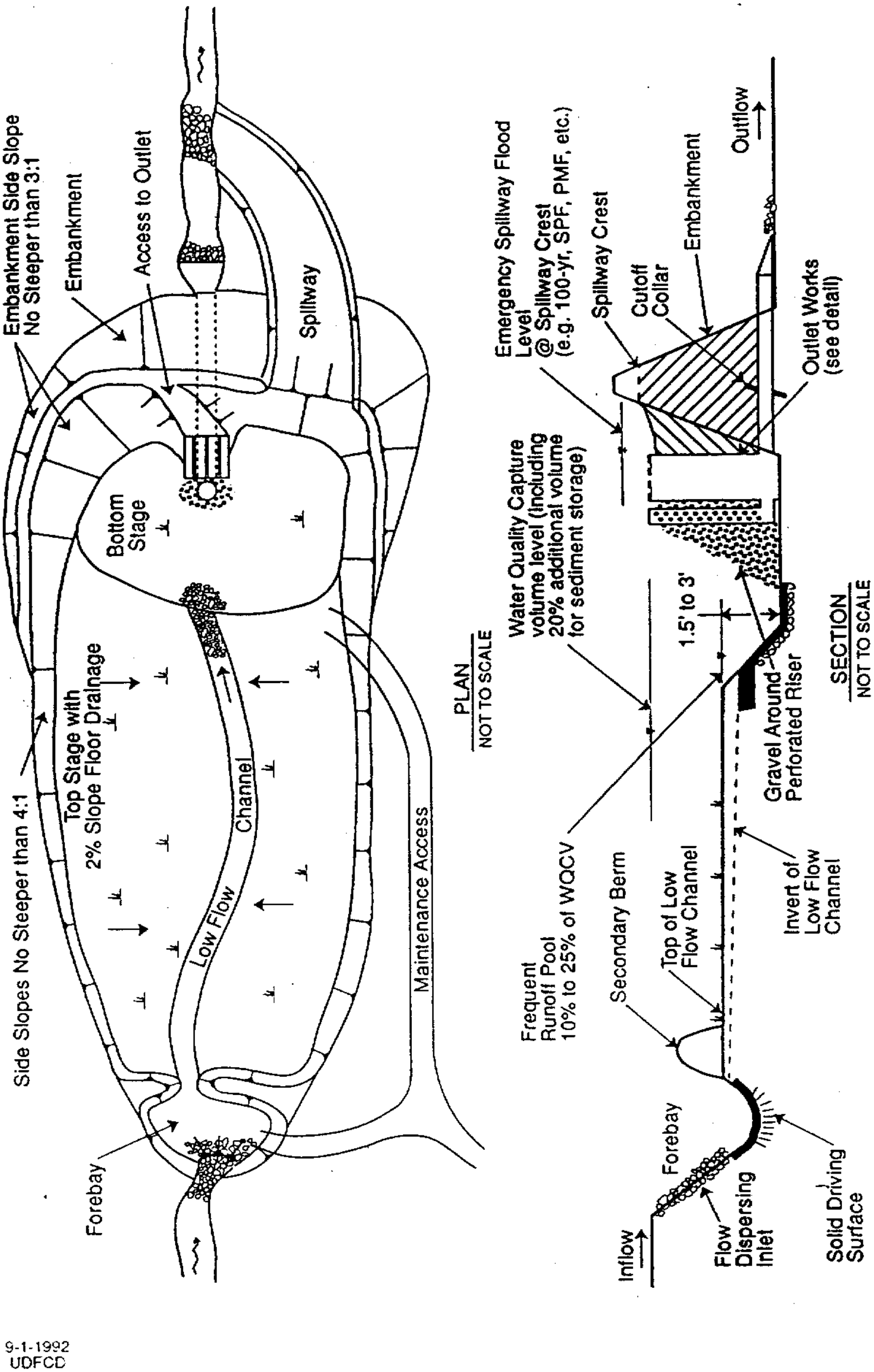
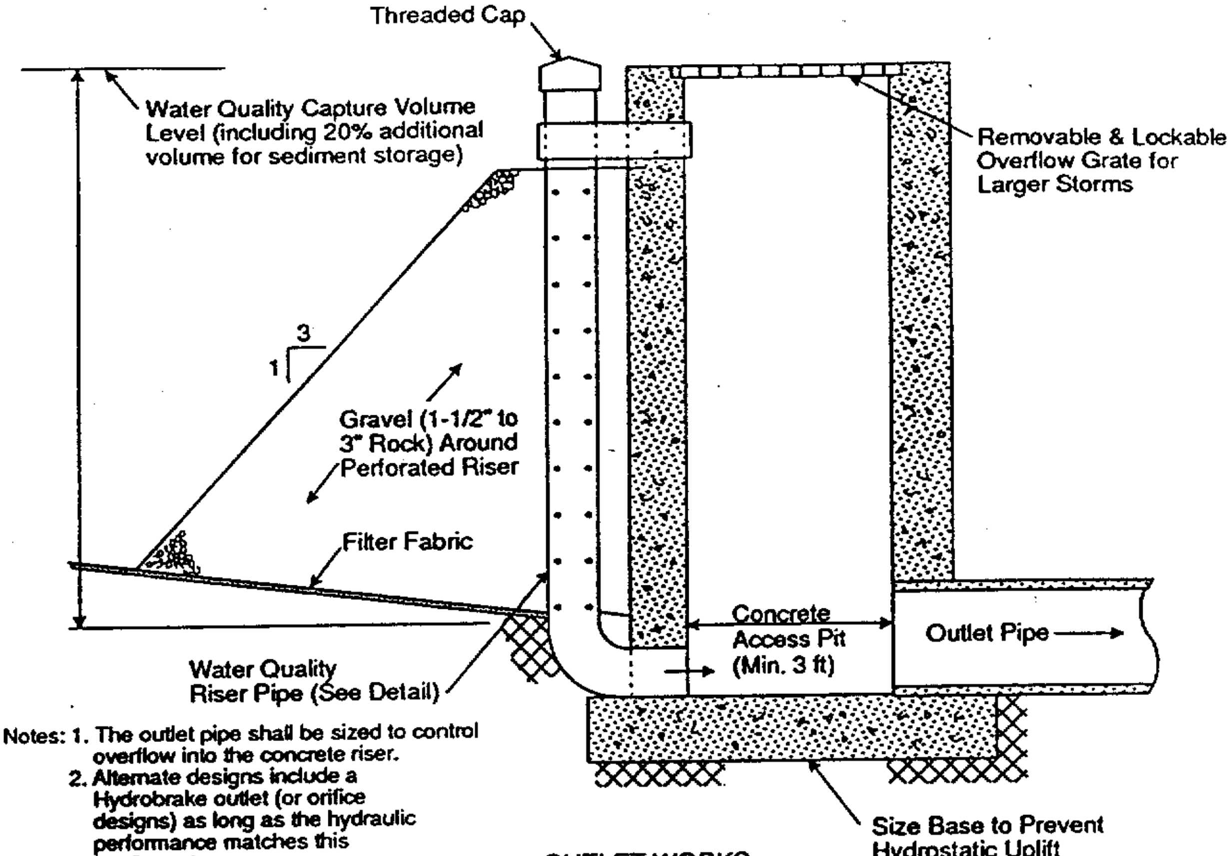


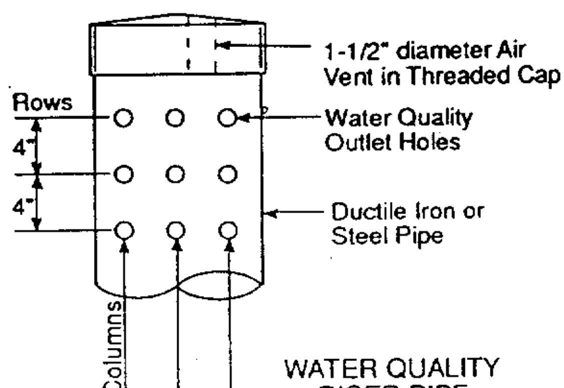
FIGURE 5-1. PLAN AND SECTION OF A DRY EXTENDED DETENTION BASIN



Notes: 1. The outlet pipe shall be sized to control overflow into the concrete riser.
2. Alternate designs include a Hydrobrake outlet (or orifice designs) as long as the hydraulic performance matches this configuration.

OUTLET WORKS
NOT TO SCALE

Notes: 1. Minimum number of holes = 8
2. Minimum hole diameter = 1/8" dia.



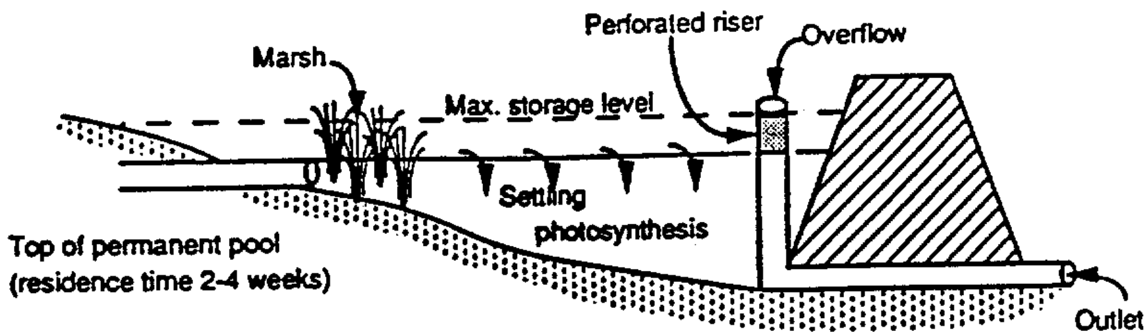
WATER QUALITY RISER PIPE
NOT TO SCALE

Maximum Number of Perforated Columns				
Riser Diameter (in.)	Hole Diameter, in.			
	1/4"	1/2"	3/4"	1"
4	8	8	--	--
6	12	12	9	--
8	16	16	12	8
10	20	20	14	10
12	24	24	18	12

Hole Diameter (in.)	Area of Hole (in.^{2})
1/8	0.013
1/4	0.049
3/8	0.110
1/2	0.196
5/8	0.307
3/4	0.442
7/8	0.601
1	0.785

FIGURE 5-2. WATER QUALITY OUTLET FOR A DRY EXTENDED DETENTION BASIN

WET DETENTION PONDS



- EFFICIENCY: EXCELLENT IF PROPERLY DESIGNED

  CAN BE POOR IF BOTTOM GOES ANOXIC

- FUNCTION: REMOVES POLLUTANTS BY SETTLING, AND DISSOLVED POLLUTANTS BIOCHEMICALLY

- MAINTENANCE: RELATIVELY FREE AFTER FIRST YEAR EXCEPT FOR MAJOR CLEANOUT AT ABOUT TEN YEARS

- AESTHETIC DESIGN CAN MAKE POND AN ASSET TO COMMUNITY. ADJACENT PROPERTY ACTUALLY INCREASES IN VALUE

- EXCELLENT AS A REGIONAL FACILITY

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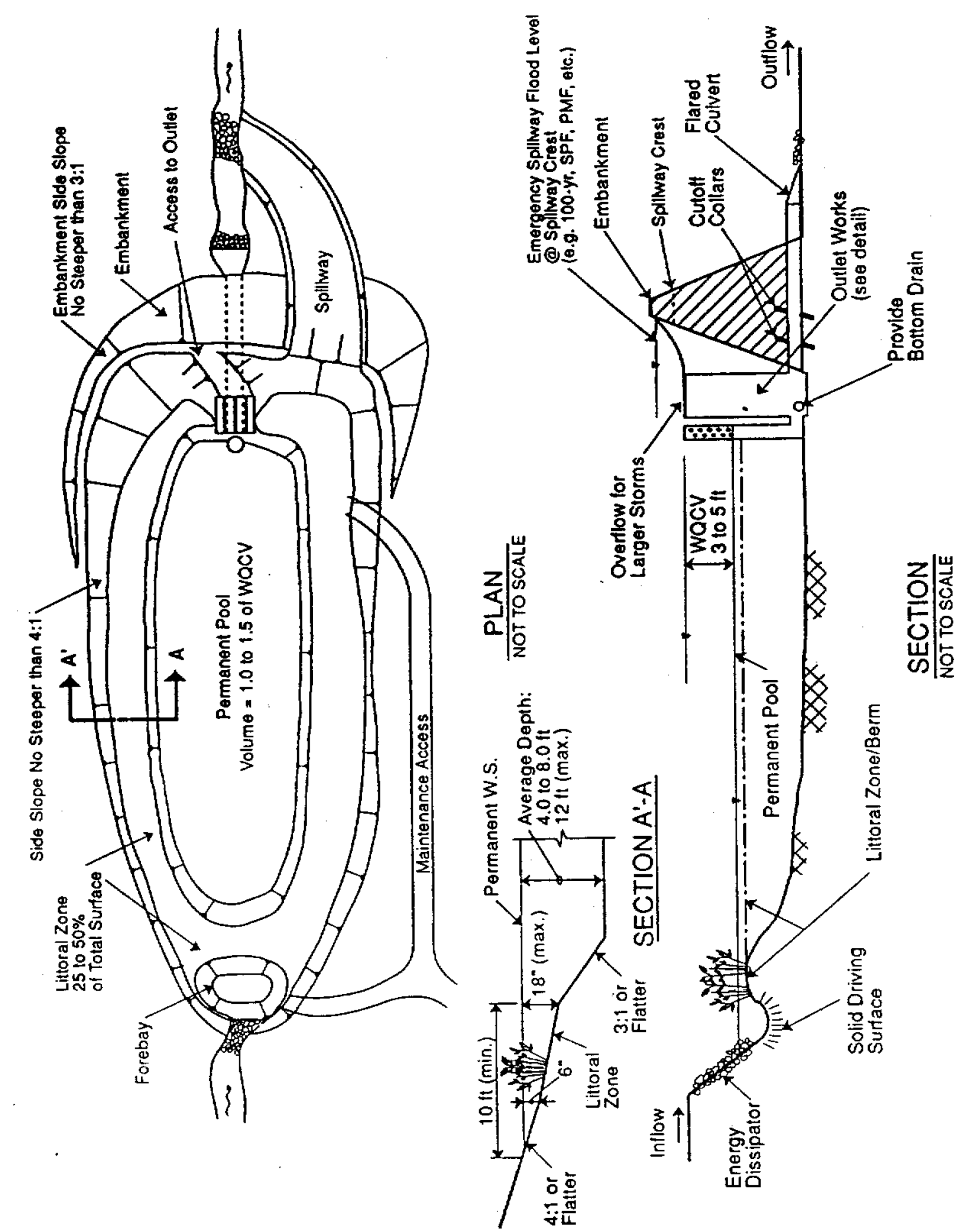
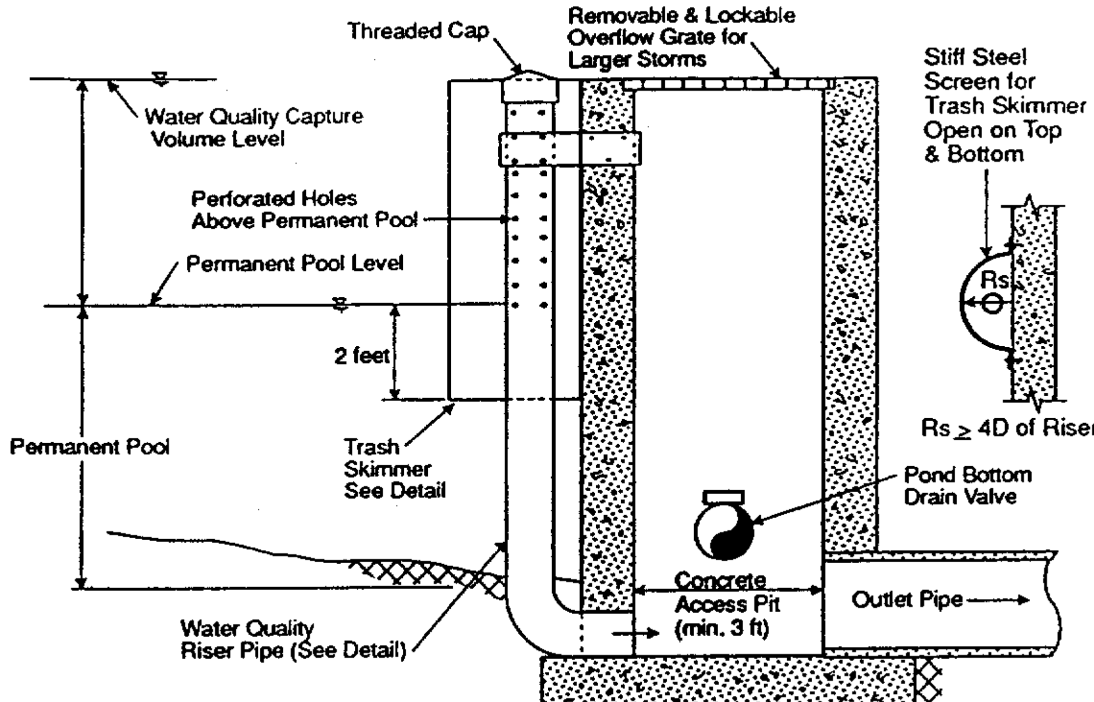


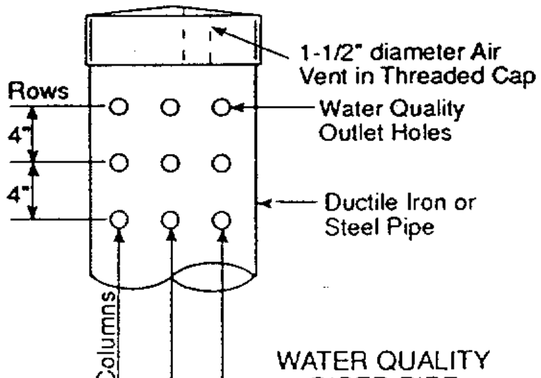
FIGURE 6-1. PLAN AND SECTION OF A WET EXTENDED DETENTION BASIN



Notes: 1. Alternate designs are acceptable as long as the hydraulics provides the required emtying times.
2. Use trash skimmer screens of stiff green steel material to protect perforated riser. Must extend from the top of the riser to 2 ft. below the permanent pool level.

OUTLET WORKS
NOT TO SCALE

Notes: 1. Minimum number of holes = 8
2. Minimum hole diameter = 1/8" Dia.

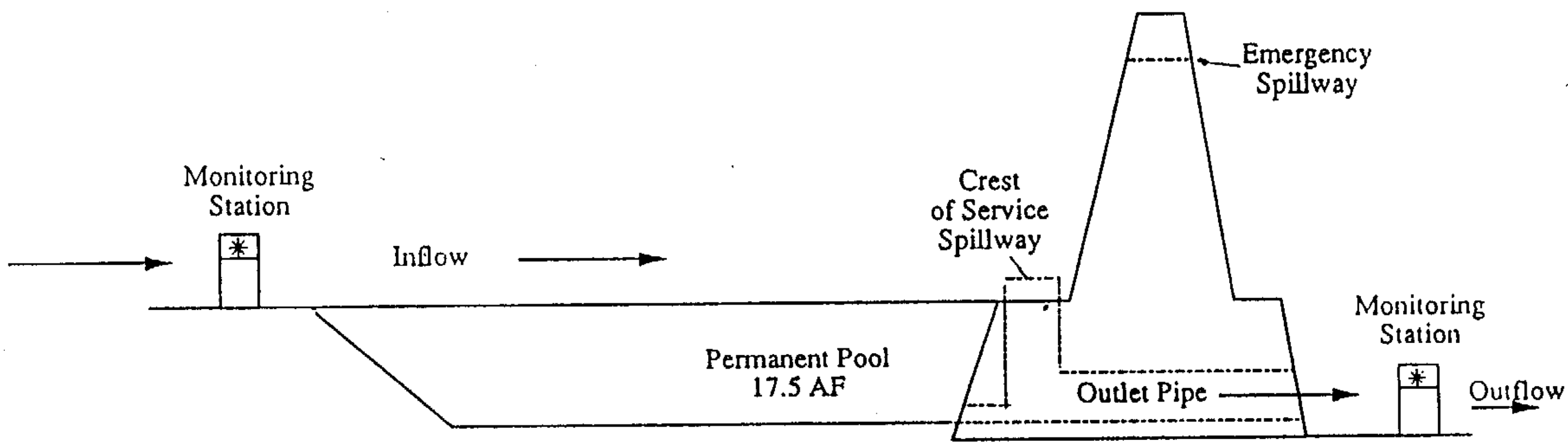


WATER QUALITY RISER PIPE
NOT TO SCALE

Maximum Number of Perforated Columns				
Riser Diameter (in.)	Hole Diameter, inches			
	1/4"	1/2"	3/4"	1"
4	8	8	--	--
6	12	12	9	--
8	16	16	12	8
10	20	20	14	10
12	24	24	18	12

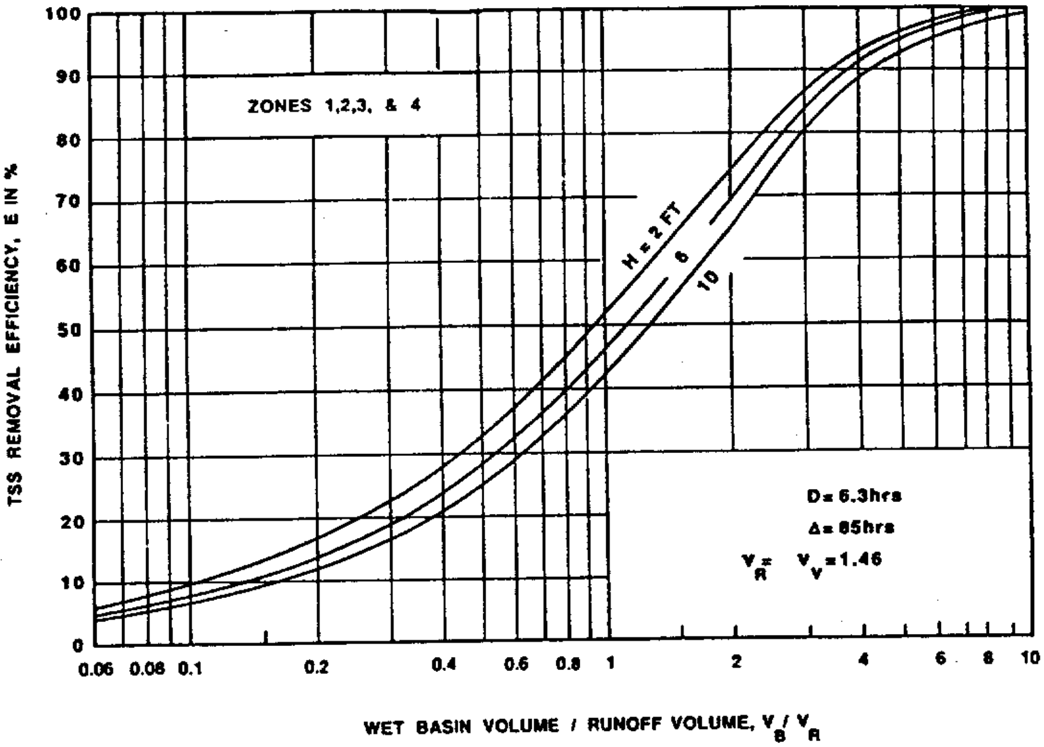
Hole Diameter (in.)	Area (in.^{2})
1/8	0.013
1/4	0.049
3/8	0.110
1/2	0.196
5/8	0.307
3/4	0.442
7/8	0.601
1	0.785

FIGURE 6-2. WATER QUALITY OUTLET FOR A WET EXTENDED DETENTION BASIN



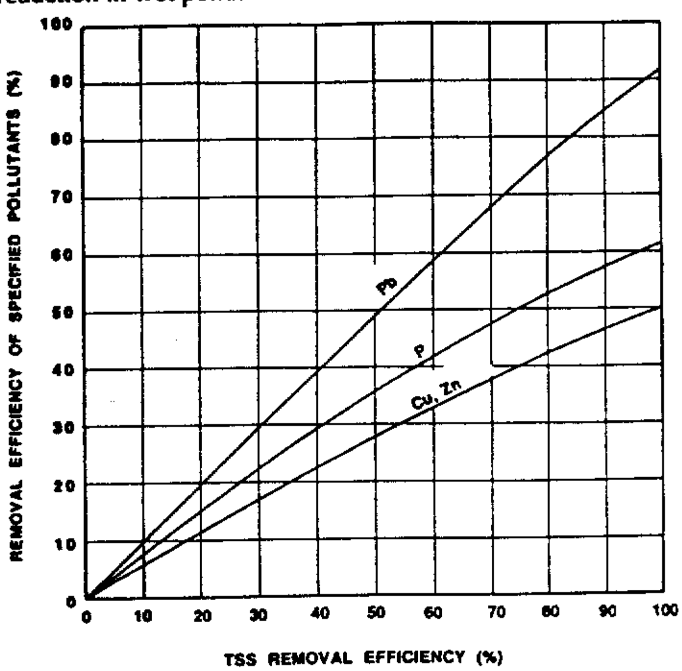
FIBURE 5B. CONCEPTUAL PLAN OF WOODHOLLOW WET POND

Figure 8.3—Total suspended solids (TSS) reduction curves for wet ponds in the United States east of the 96th meridian.



Source: Dorman et al. 1988.

Figure 8.4—Reductions of lead (Pb), phosphorus (P), copper (Cu), and zinc (Zn) in relation to total suspended solids (TSS) reduction in wet pond.



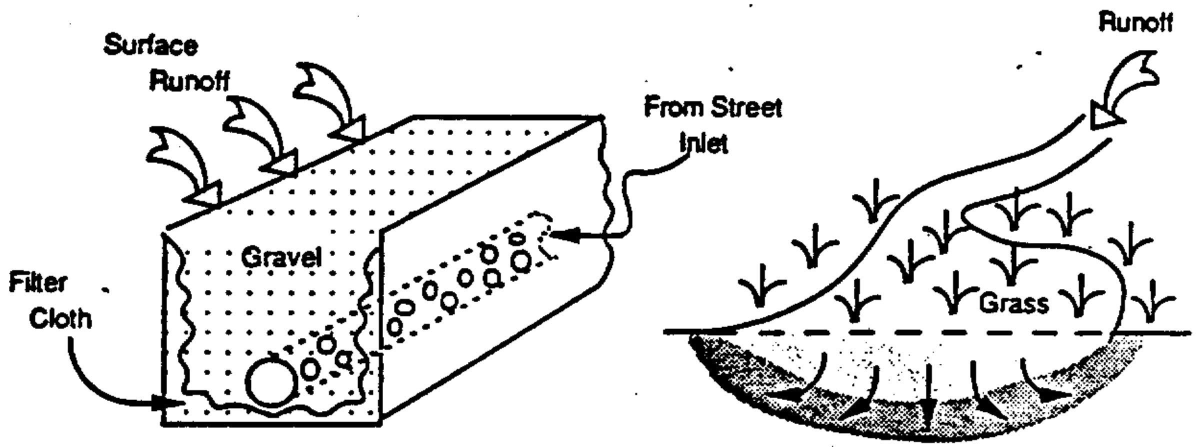
Source: Dorman et al. 1988.

A number of agencies have adopted the NURP pond guidelines as a design basis, including the Metropolitan Washington Council of Governments (Schueler, 1987), the Federal Highway Administration (Dorman et al. 1988), and the state of California (Camp, Dresser, McKee et al. 1993). The guidelines help set performance objectives for pollutants of interest and calculate the pool storage volume from the graph and climatological statistics for the region to reach those objectives.

Other agencies have specified either a certain runoff quantity or a precipitation event as the design basis. For example, treating the first 1 in (2.5 cm) of runoff provides treatment to most storms and total runoff volume in an average year. The Washington Department of Ecology (1992) selected the six-month, 24-hour rainfall event as the "water quality design storm." The treatment system (the pool storage in a wet pond) should provide sufficient volume to hold runoff from this storm. In Seattle, this event produces about 1.2 in (3.05 cm) of rain. With a mean rain storm of 0.48 in (1.22 cm) at this location, the NURP volume ratio is thus approximately 2.5 for any runoff coefficient.

"Horner et. al., 1994"

INFILTRATION DEVICES



- EFFICIENCY: EXCELLENT (Small depressional infiltration basins are great onsite controls)
- FUNCTION: INFILTRATES RUNOFF TO GROUNDWATER, SOIL FILTERS POLLUTANTS
- MAINTENANCE INTENSIVE (Mowing, upstream erosion control)
- NON-FUNCTIONAL IF PLUGGED
- SOIL MUST BE HIGHLY PERMEABLE, AND WET SEASON WATER TABLE 3 FT. BELOW BOTTOM
- EXPERIENCE WITH UNDER-DRAINED INFILTRATION BASINS IS POOR

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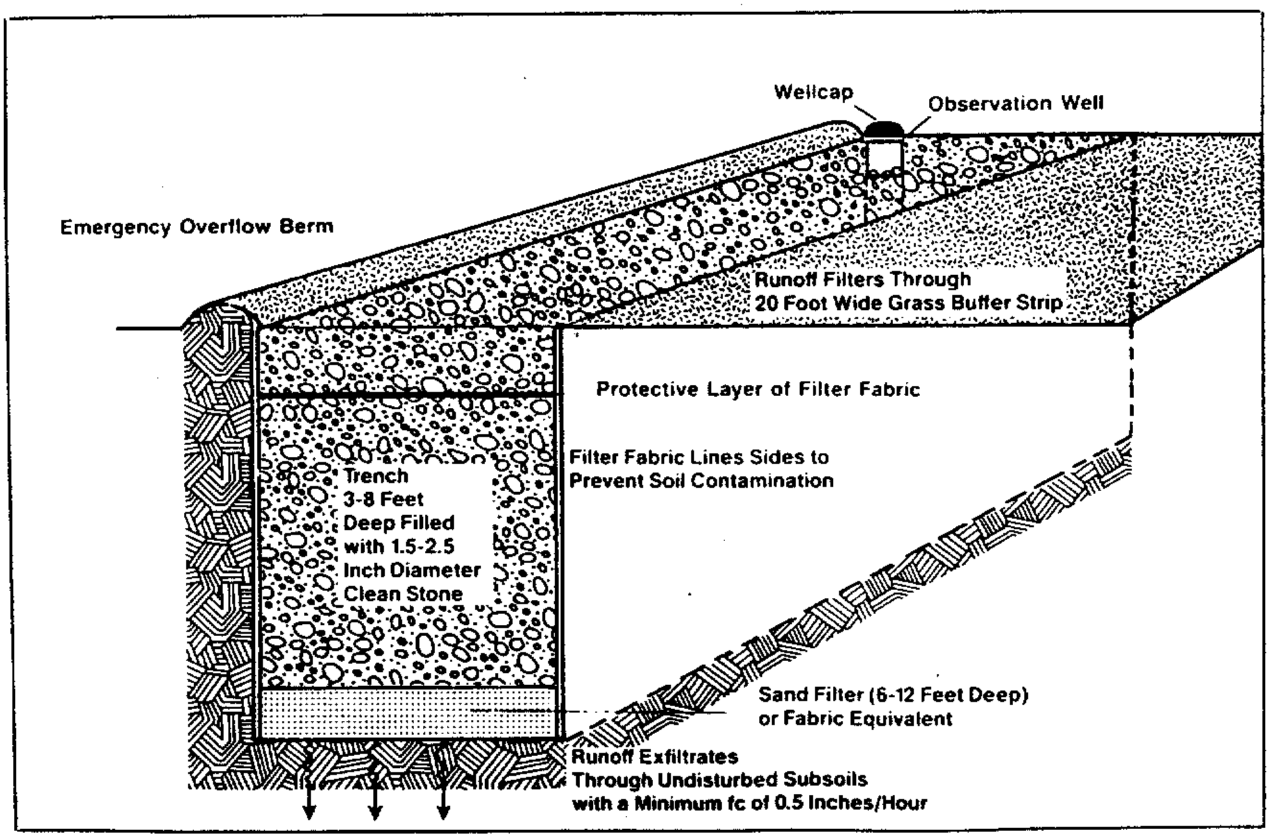
CHAPTER 5: INFILTRATION TRENCHES

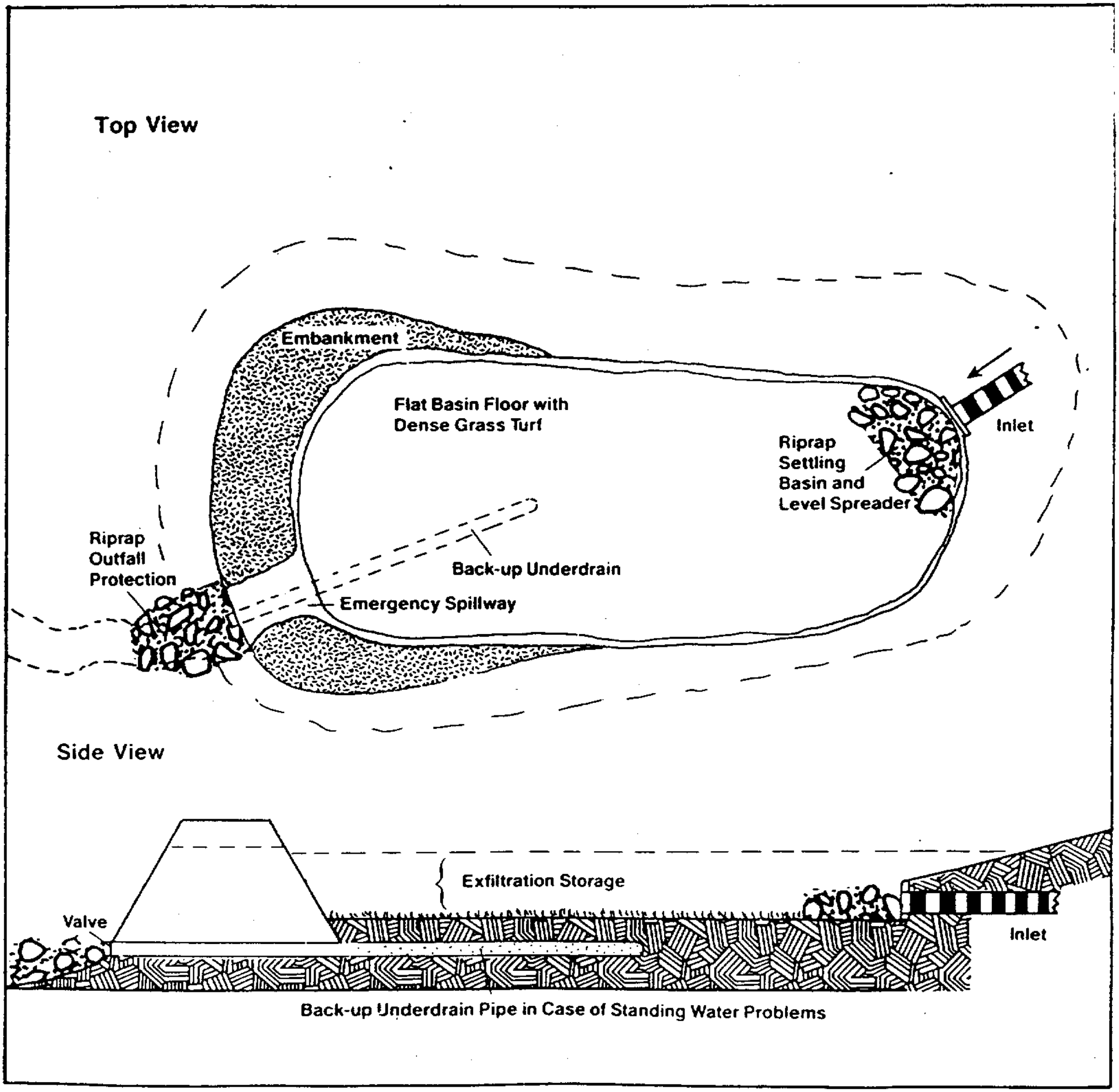
Infiltration trenches are an adaptable BMP that effectively remove both soluble and particulate pollutants. As with other infiltration systems, trenches are not intended to trap coarse sediments. Grass buffers (for surface trenches) or special inlets (for underground trenches) must be installed to capture sediment before it enters the trench. Depending on the degree of storage/exfiltration achieved, trenches can provide groundwater recharge, low flow augmentation and localized streambank erosion control. Individual trenches are primarily an on-site control, and are seldom practical or economical on sites larger than 5 or 10 acres. Trenches are only feasible when soils are permeable and the water table and bedrock are situated well below the bottom of the trench. Aside from regular inspections and more rigorous sediment and erosion control, trenches have limited routine maintenance requirements. However, trenches will prematurely clog if sediment is not kept out before, during and after construction of a site. If a trench does become severely clogged, partial or complete replacement of the structure may be required.

Figure 5.1: Schematic of an Infiltration Trench



"WASHCOG, 1987"

Figure 6.1: Schematic of an Infiltration Basin



SCHUELER, 1987

water can be widely distributed to increase the percolation potential. If the grade permits, it can be discharged on the surface, after being treated while passing through the upper soils. Constructed soil systems usually require underdrains. While these systems could be considered filtration practices, this guide considers them under infiltration, reserving the filtration category for units constructed in boxes and generally having a conventional surface discharge.

The most crucial issues in using infiltration devices, in addition to soil suitability, are avoiding clogging and the potential to contaminate groundwater. Infiltration facilities should be constructed in medium textured soils. They are generally unsuitable for clay because of restricted percolation and gravel and coarse sands because of the risk of groundwater contamination, unless effective pretreatment is provided. An impermeable soil layer close to the surface may need to be penetrated. If the layer is too thick, underdrains, and possibly imported soil to provide sufficient treatment depth, may be required (Entranco Eng. 1989). As a minimum measure to prevent clogging, infiltration facilities should require a pretreatment device to settle larger solids and reject runoff from eroding construction sites.

Among the various runoff treatment options, only soil infiltration systems have been reliable in removing soluble phosphorus (Minton, 1987). This result likely applies to other relatively soluble pollutants as well. Reduction depends principally on how effectively the system prevents runoff from directly entering surface water. Reduction can be complete if surface effluent is absent and percolating water cannot get to surface water through interflow in the unsaturated zone or via rapid transit of groundwater in the saturated zone. In other circumstances, dissolved pollutant reduction is incomplete but is still higher than with any other treatment method.

Expected Performance

This manual classifies performance of soil infiltration systems as follows:

- Natural soil column infiltration basins, trenches, and perforated pipes with and without underdrains;
- Underdrained systems with selected filtration media—sand and peat-sand; and
- Porous pavements.

▌*Natural Soil Systems.* In a natural system without underdrains, the system's hydrology (directness of connection with surface water) determines how much runoff is captured and how efficient the treatment. Alternative design rules for infiltration basins and their estimated runoff reductions and pollutant removals (Schueler, 1987) are to store and infiltrate either (1) 0.5 in (1.27 cm) of runoff per impervious acre contributing, (2) the runoff resulting from a 1-inch rainfall event, or (3) the two-year frequency runoff volume. Table 8.8 estimates pollutant removals.

With the first rule, Schueler estimates that 40 to 50 percent of the runoff volume would be captured in the soil over the long term. This would rise to 65 to 75 percent with the second rule, depending on the soil and the amount of impervious area (the NURP database used to make the estimates

Table 8.8—Estimated long-term pollutant removal rates (percent) for infiltration basins.

POLLUTANT	SIZED BASED ON		
	0.5-IN RUNOFF/IMPERV. ACRE	RUNOFF FROM 1-IN RAIN	2-YEAR STORM RUNOFF VOLUME
Total suspended solids	75	90	99
Total phosphorus	50-55	60-70	65-75
Total nitrogen	45-55	55-60	60-70
Metals	75-80	85-90	95-99
Biochemical oxygen demand	70	80	90
Bacteria	75	90	98

Source: Schueler, 1987.

"Horner et. al., 1994"

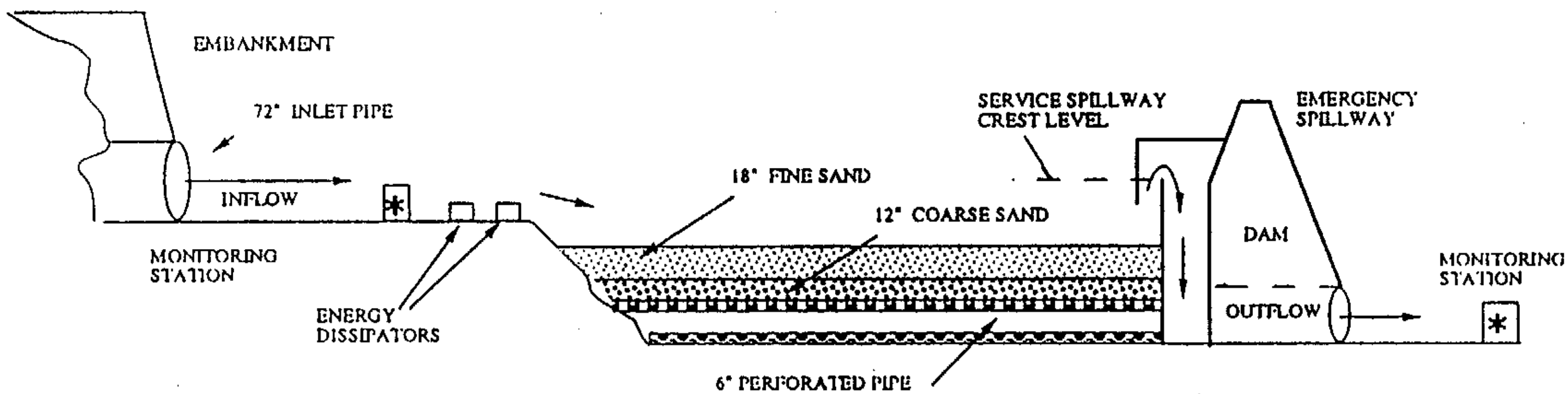


FIGURE 3B. CONCEPTUAL PLAN OF BARTON CREEK SQUARE MALL STORMWATER DETENTION/FILTRATION POND

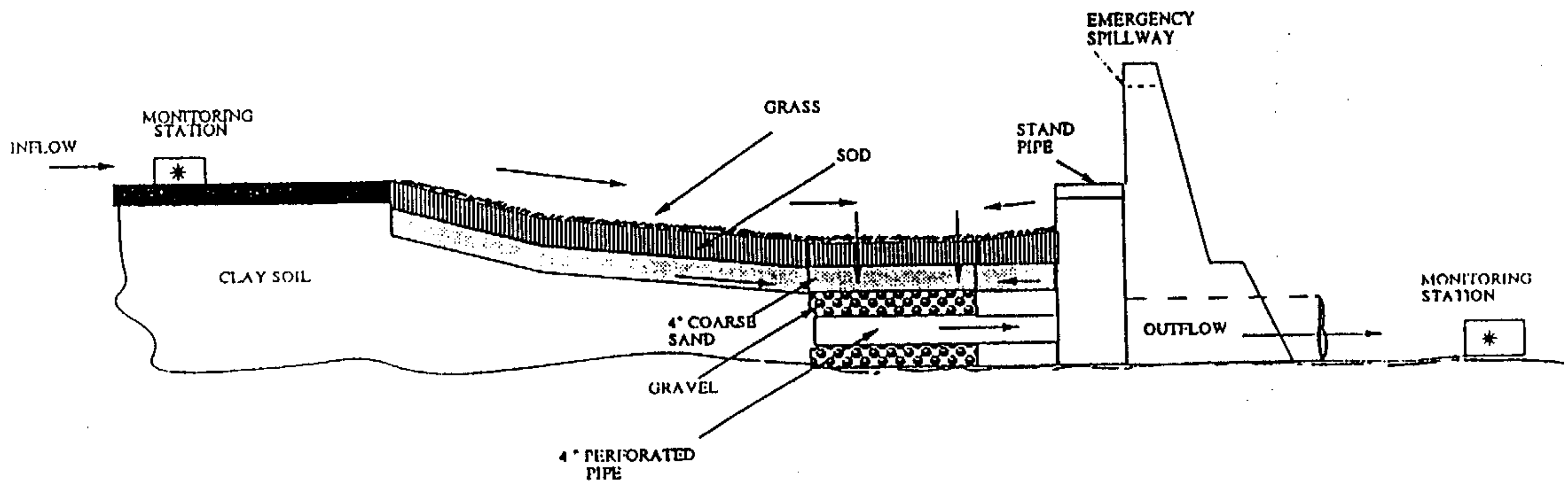


FIGURE 2B. CONCEPTUAL PLAN OF HIGHWOOD APARTMENT SEDIMENTATION/FILTRATION BASIN

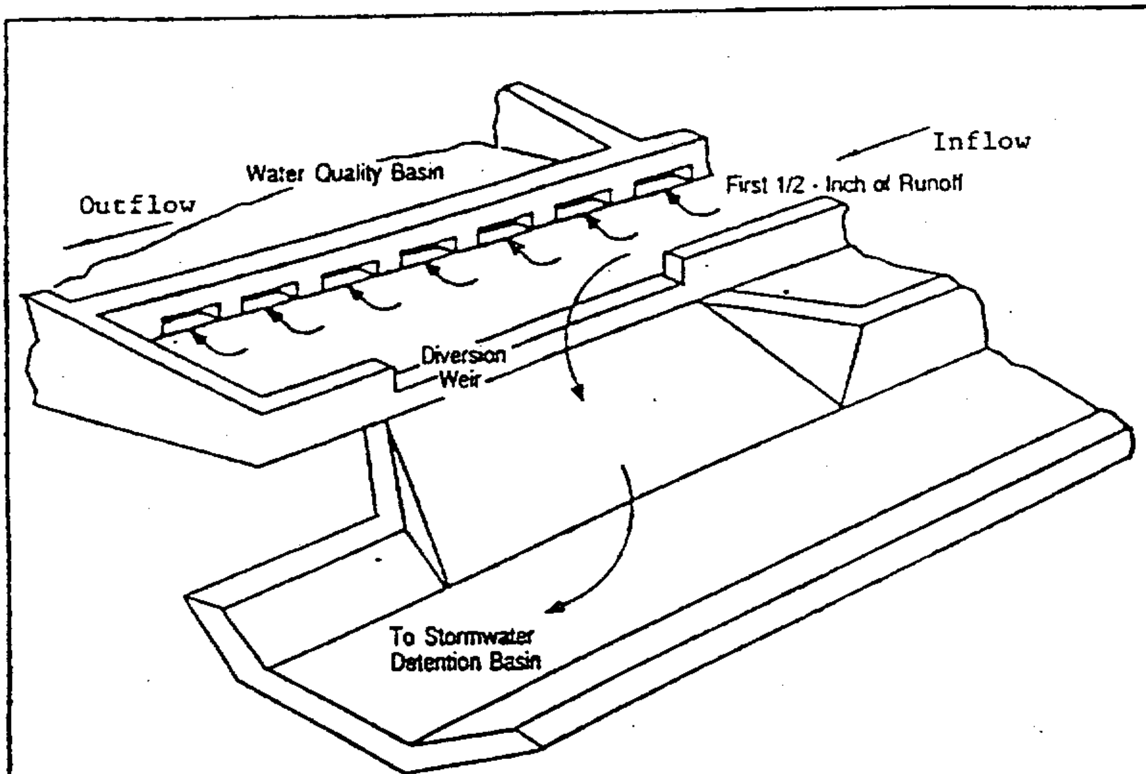


FIGURE 4B. CONCEPTUAL PLAN OF JOLLYVILLE FILTRATION POND I — BASIN ARRANGEMENT

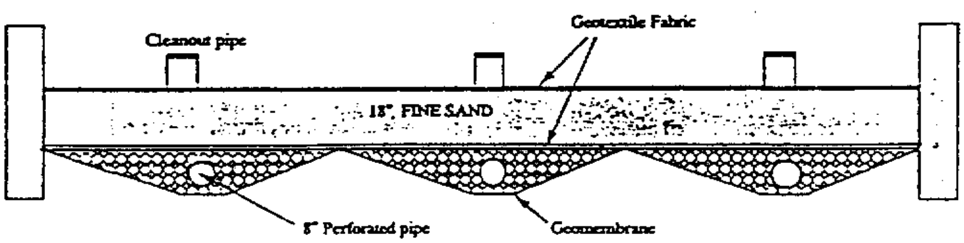
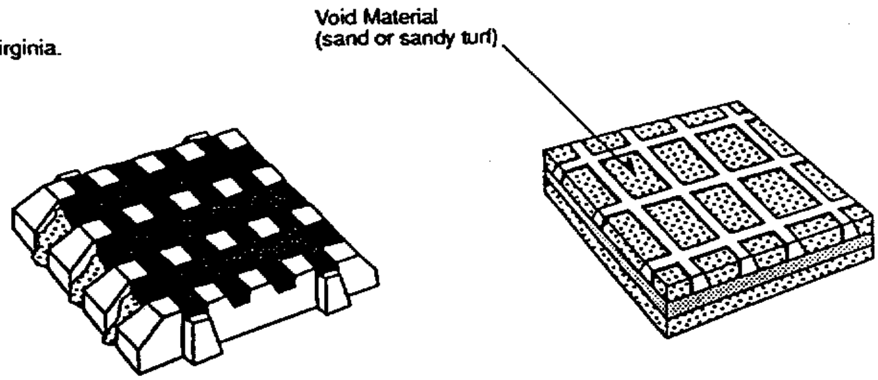
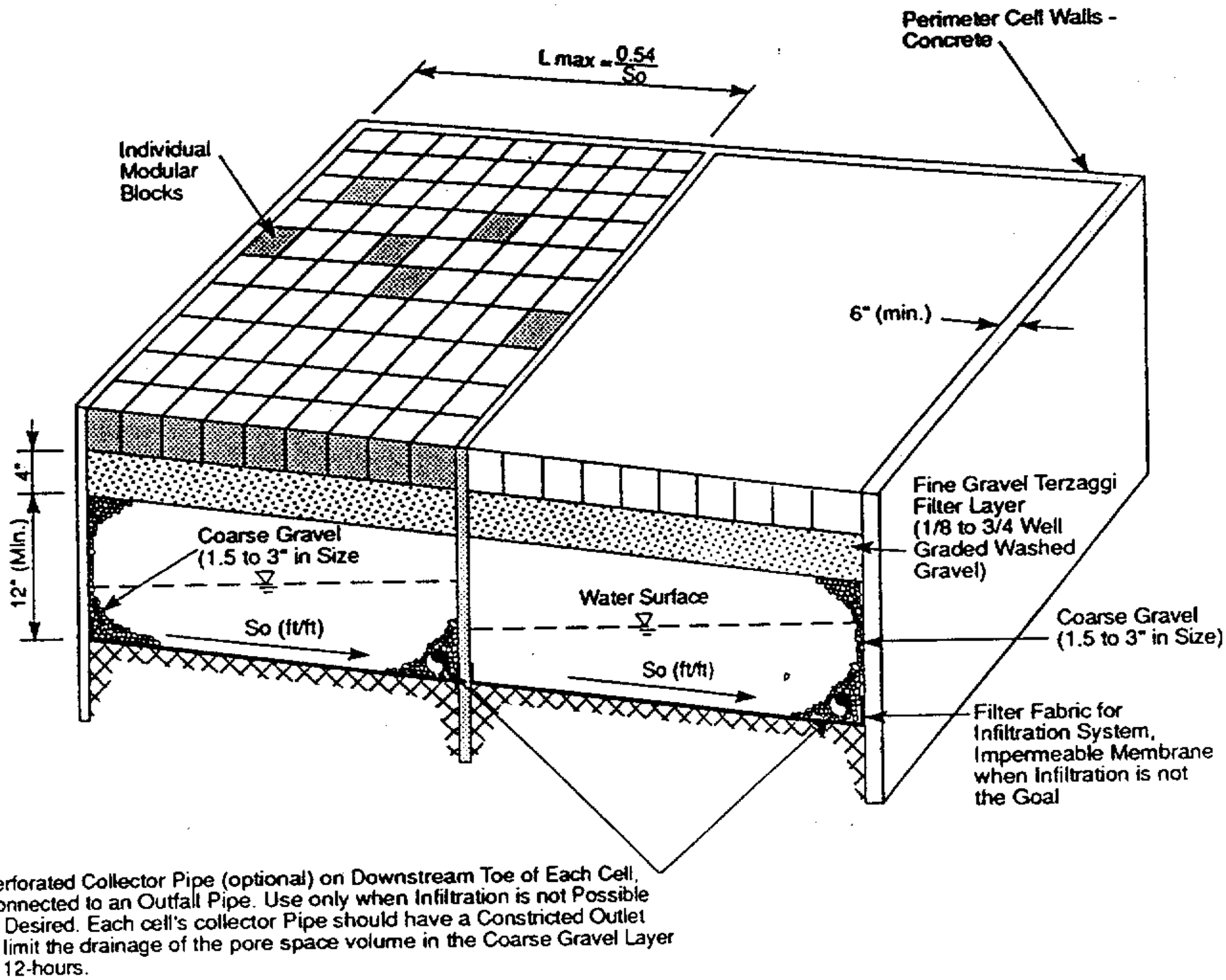


FIGURE 4B. CONCEPTUAL PLAN OF JOLLYVILLE FILTRATION, CROSS-SECTION

Source: State of Virginia.



TWO EXAMPLES OF INDIVIDUAL CONCRETE MODULAR PAVING BLOCK

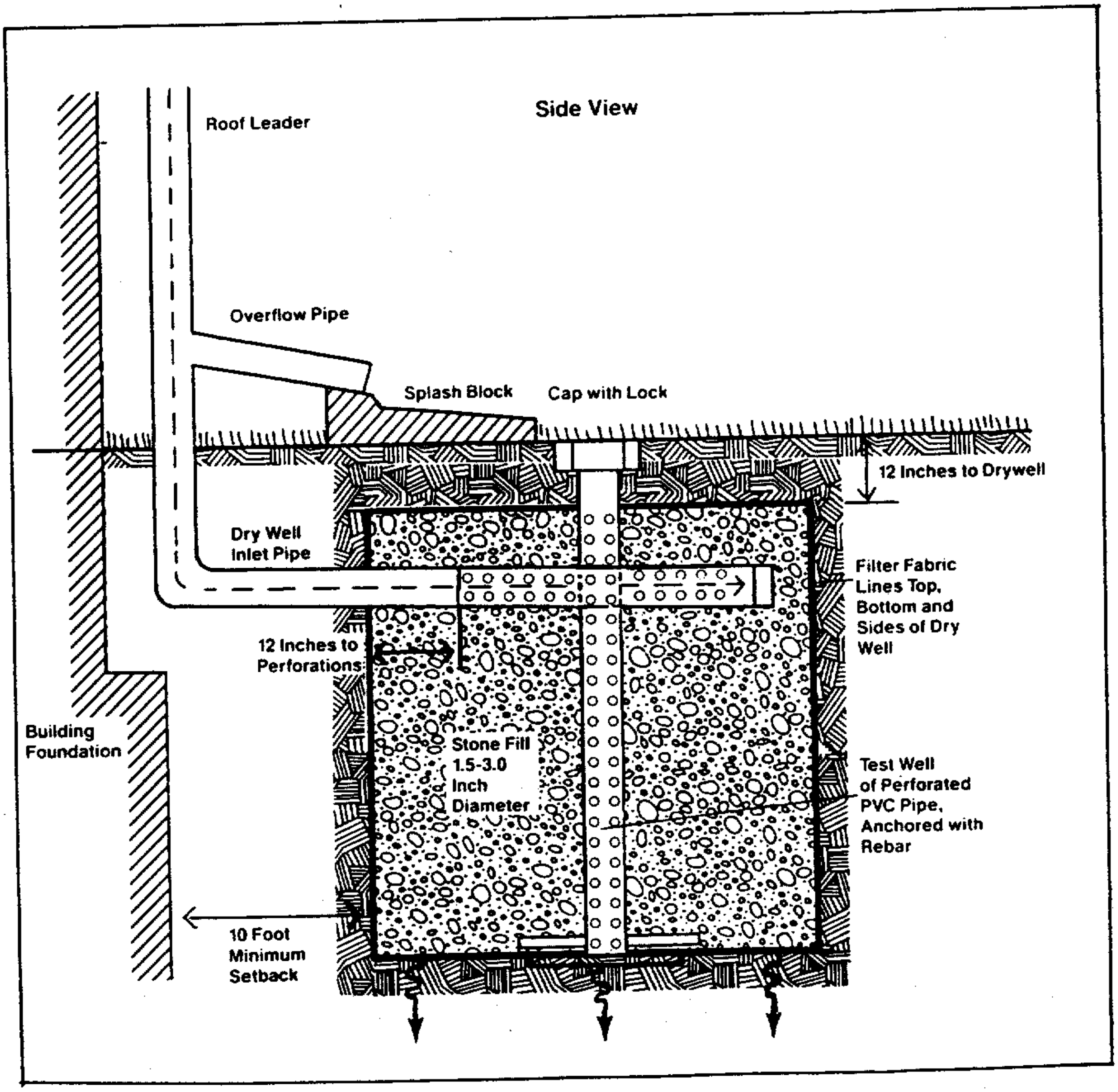


PERSPECTIVE OF SIDE-BY-SIDE MODULAR BLOCK CELLS

FIGURE 8-1. MODULAR BLOCK POROUS PAVEMENT

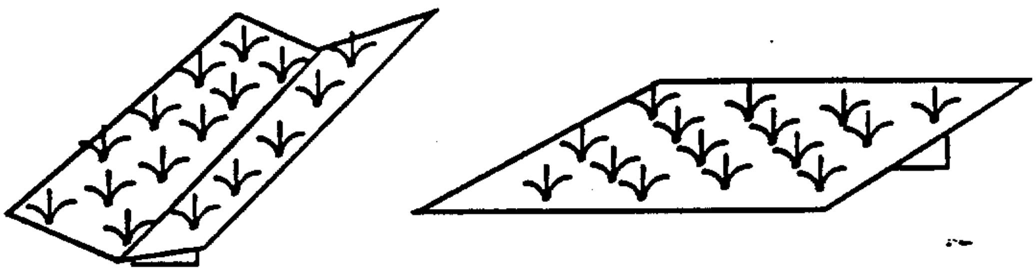
DESIGN 4: Dry Well Designs. (Figure 5.8). Dry wells are a basic trench variation which are designed exclusively to accept rooftop runoff from residential or commercial buildings (Figure 5.8). Additional guidance on dry well design is available from Md WRA (1984). Basically, the leader from the roof is extended into an underground trench, which is situated a minimum of ten feet away from the building foundation. Rooftop gutter screens are needed to trap any particles, leaves and other debris, and must be regularly cleared.

Figure 5.8: Dry Well Design (adapted from Md WRA, 1986)



"WASHCOG, 1987"

SWALES AND FILTER STRIPS AS CONTROLS



- EFFICIENCY: LOW
- FUNCTION: SLOW RUNOFF RATE, MINOR FILTERING AND INFILTRATION
- MAINTENANCE INTENSIVE (MOWING)
- KEEP SIDESLOPES OF SWALE SMALL
- USE IN COMBINATION WITH OTHER CONTROLS

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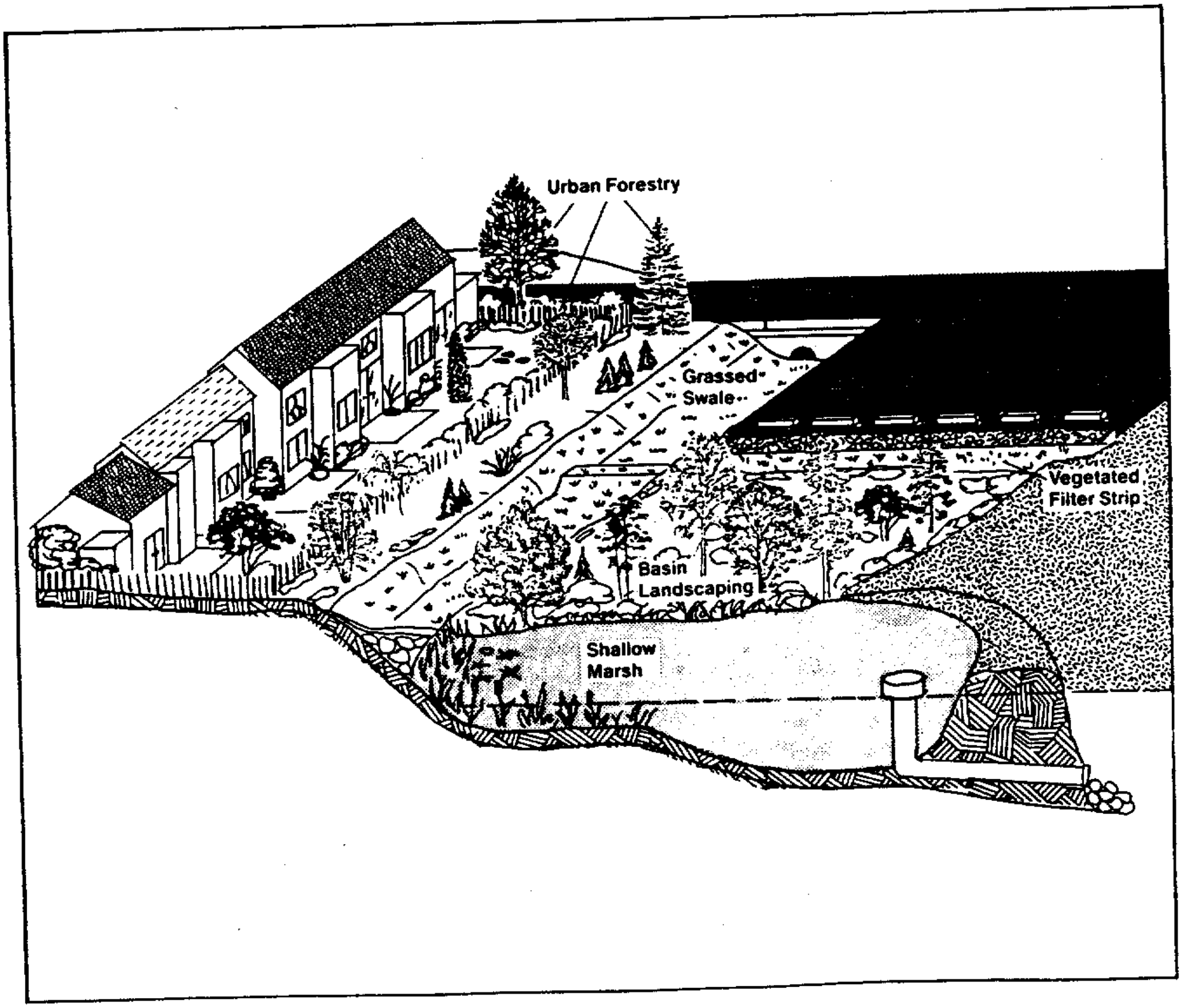
CHAPTER 9: VEGETATIVE BMPs

This section reviews a diverse series of landscaping practices that can be applied to portions of the urban drainage system, including:

- Grassed Swales
- Filter Strips
- Urban Forestry
- Basin Landscaping
- Shallow Marsh Creation

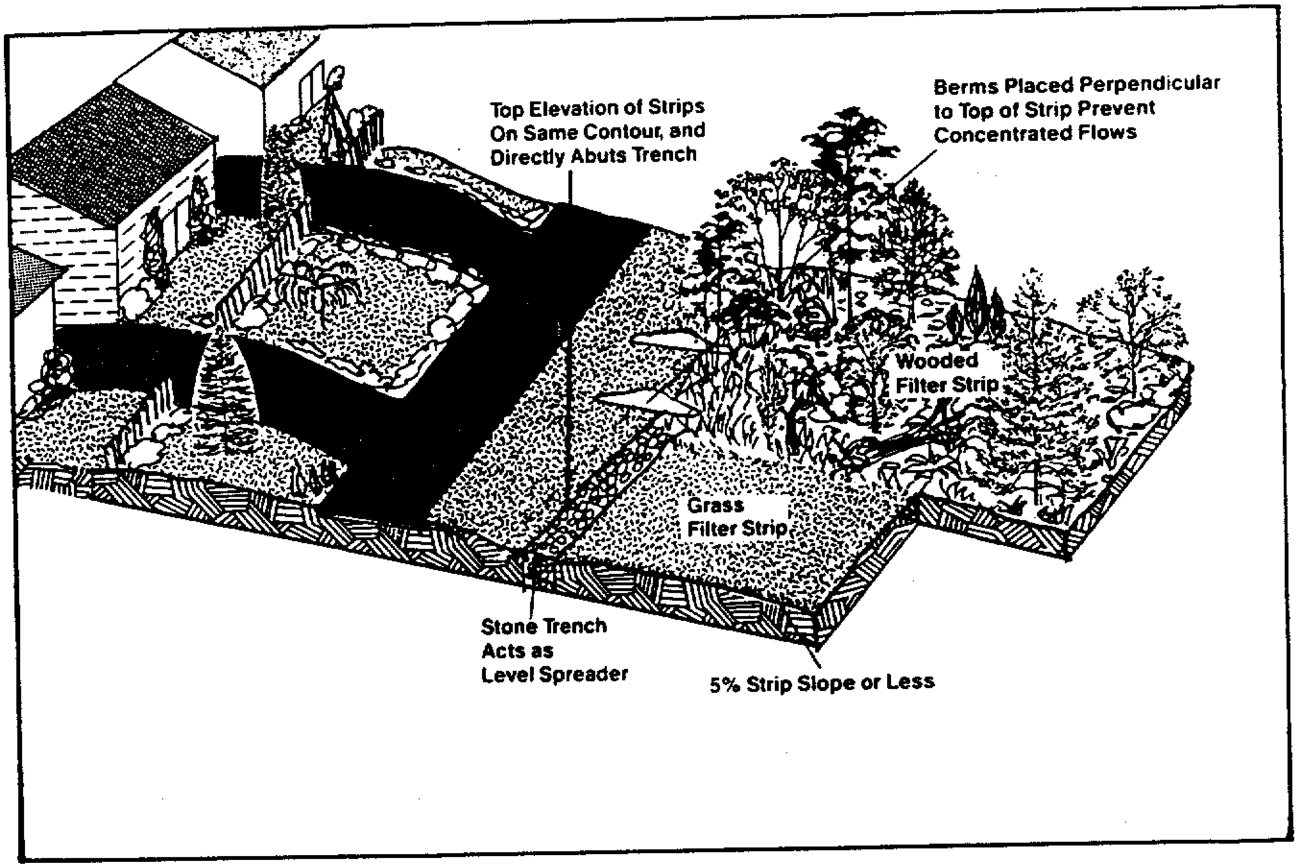
Figure 9.1: Vegetative BMPs for a Site



"WASHCOG, 1987"

become a valuable community amenity, providing wildlife habitat, screening, and stream protection. Grass filter strips are also extensively used to protect surface infiltration trenches from clogging by sediment.

Figure 9.3: Schematic of a Filter Strip



Stormwater Benefits

Filter strips do not provide enough storage or infiltration to effectively reduce peak discharges to predevelopment levels for design storms (Wong and McCuen, 1982). Typically, filter strips are viewed as one component in an integrated stormwater management system. Thus, the strips can lower runoff velocity (and, consequently, the watershed time of concentration), slightly reduce both runoff volume and watershed imperviousness, and contribute to groundwater recharge. At some sites, filter strips may help to reduce the size and cost of downstream control facilities. Filter strips are also of great value in preserving the riparian zone and stabilizing streambanks.

Pollutant Removal

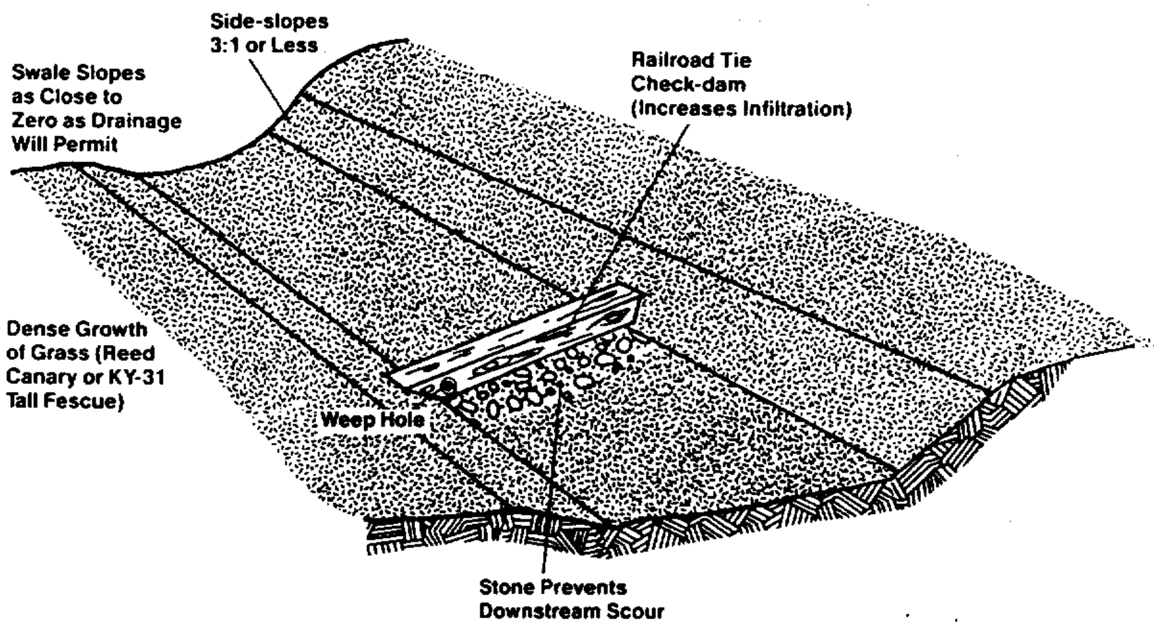
Pollutant removal mechanisms in filter strips are similar to those discussed for grass swales. Results from some small test plots (Barfield et al., 1977) and several independent modeling studies (Wong and McCuen, 1982; Pitt, 1986, Overcash et al., 1981; Tollner et al., 1982) all suggest that filter strips are effective in removing particulate pollutants such as sediment, organic material and many trace metals. The rate of removal appears to be a function of the length, slope and soil permeability of the strip, the size of the contributing runoff area, and the runoff velocity.

"WASHCOG, 1987"

strength, and as a result, have less infiltration capacity than undisturbed soils. In addition, the same rain that supplies runoff to a swale often has previously saturated the soils of the swale. Consequently, infiltration rates in a swale will almost always be near the minimum rates for the local soil type.

The hydrologic performance of swales can be improved if check dams are used to temporarily pond runoff. Appropriate design techniques are provided in Md WRA (1984).

Figure 9.2: Schematic of a Grassed Swale



Pollutant Removal

Pollutants are removed by the filtering action of the grass, deposition in low velocity areas, or by infiltration into the subsoil. Field monitoring has provided mixed results as to the extent of pollutant removal performed by swales. Kercher et al. (1983) and Yousef et al. (1985) reported moderate to high removal of particulate pollutants in low gradient, densely vegetated swales in Florida. In contrast, Oakland (1983) found low to moderate removal of particulate pollutants and negligible removal of soluble pollutants in a low-gradient swale, underlain by relatively impermeable soils in New Hampshire.

- Avoid detergent use upstream to prevent chemical emulsification;
- Provide a forebay sized at 20 ft^2 (1.86 m^2) of surface area per 10,000 ft^2 (929.0 m^2) of drainage area; and
- Provide an afterbay in which to place absorbents.

Vegetative Practices

Swales and Filter Strips

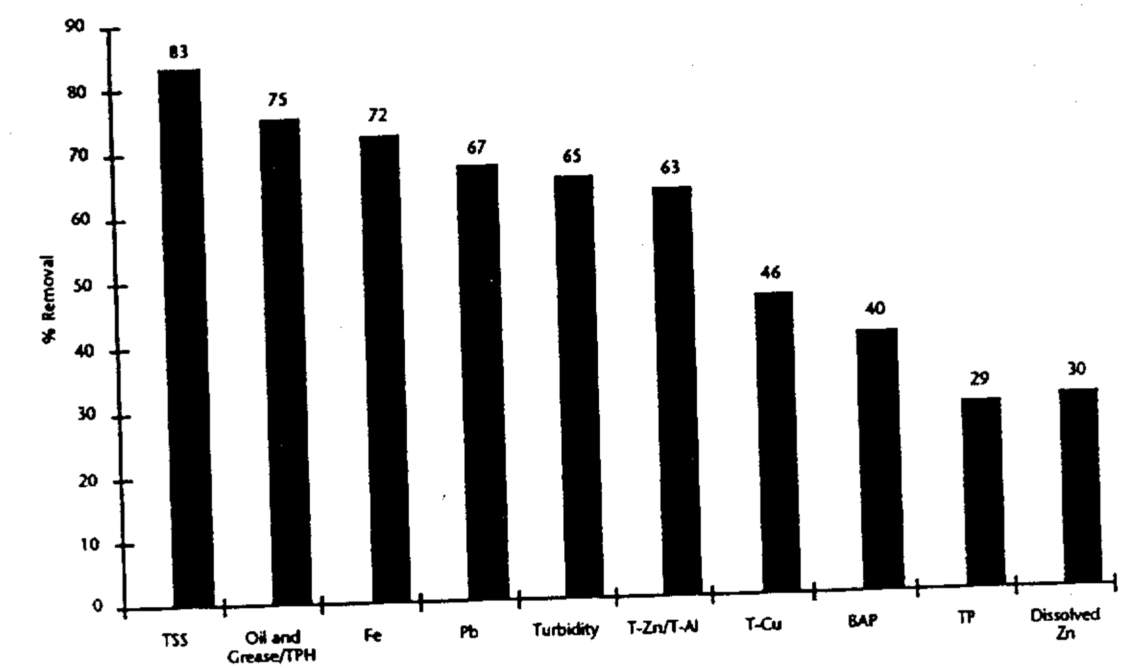
Treatment practices that use terrestrial grasses and other fine herbaceous plants are sometimes called biofiltration. These plants can be installed in a channel in which water flows at some depth—a swale—or on a broad surface area that has sheet flow—a filter strip. Biofilters can also have wetland plants in areas with the hydrology to sustain them.

A vegetated treatment strives for a plant stand that serves as a good filter. Ideal characteristics are dense, uniform growth of fine-stemmed plants tolerant of the area's water and climatological, soil, and pest conditions. Native plants generally combine the best properties. Plants serve mainly as filters; pollutant uptake is not a very important removal mechanism. Therefore, a number of species and mixes appropriate to the area will work equally well.

■ *Sizing Calculations and Expected Performance.* The results of a performance investigation of a grass swale, recently completed in the Puget Sound area of Washington (Municipality Metro. Seattle, 1992), refined a previously developed design procedure and recommended design features consistent with good performance. The report details the full design procedure, criteria, and guidelines that are excerpted here.

Figure 8.5, which summarizes the performance results, shows that the swale was relatively effective in capturing solids, oils, and the least soluble metals. The swale was less effective for more soluble metals, especially their dissolved fractions, and less yet for phosphorus. Nitrogen (not shown) exhibited little if any removal; fecal coliform's capture was inconsistent. Therefore, biofilters should generally be considered the sole

Figure 8.5—Average pollutant removal over six storms in a grass swale with an average hydraulic residence time of nine minutes.



TPH = total petroleum hydrocarbons
T = total
BAP = biologically available phosphorus

Source: Municipality of Metro. Seattle, 1992.

"Horner et. al., 1994"

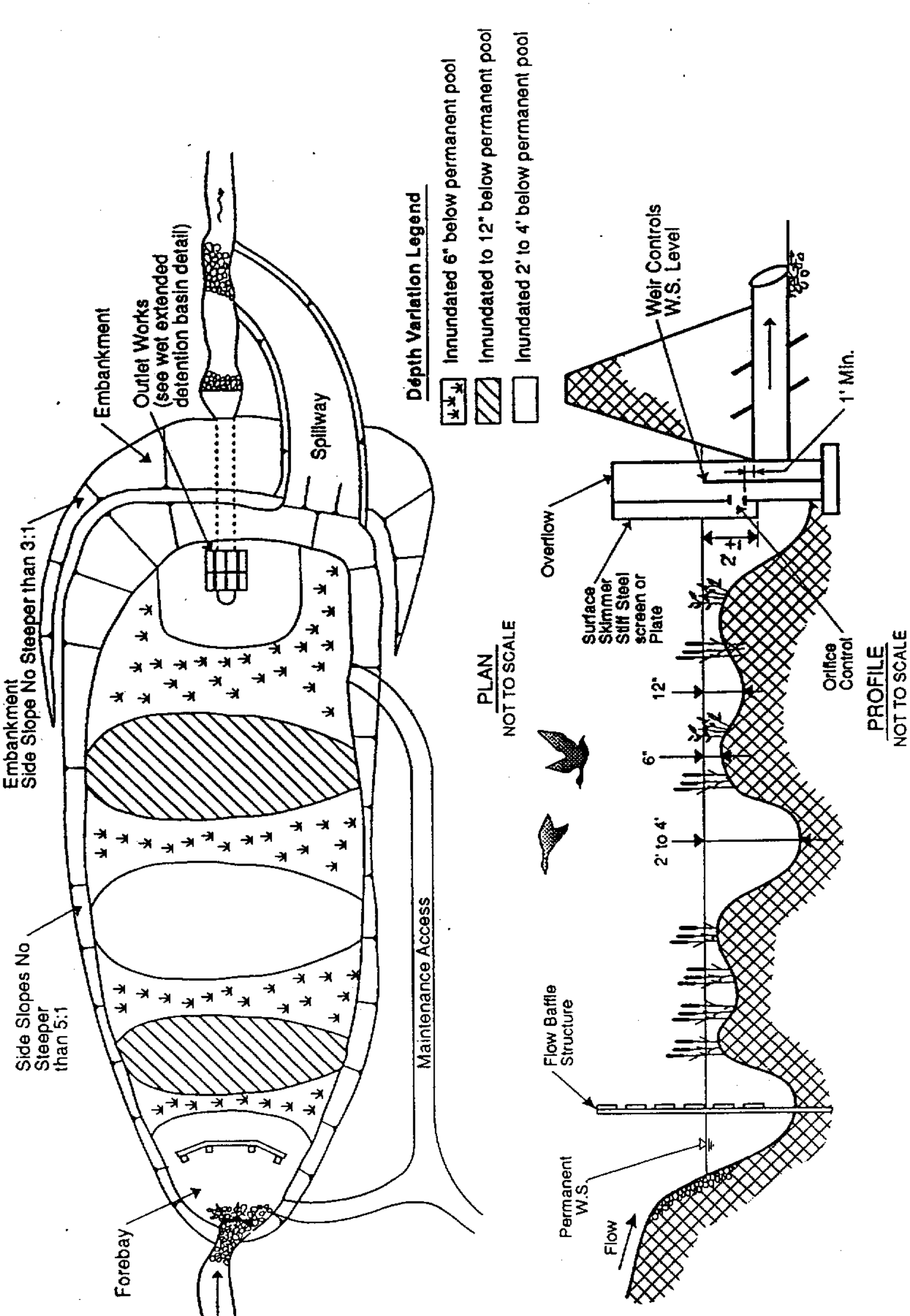


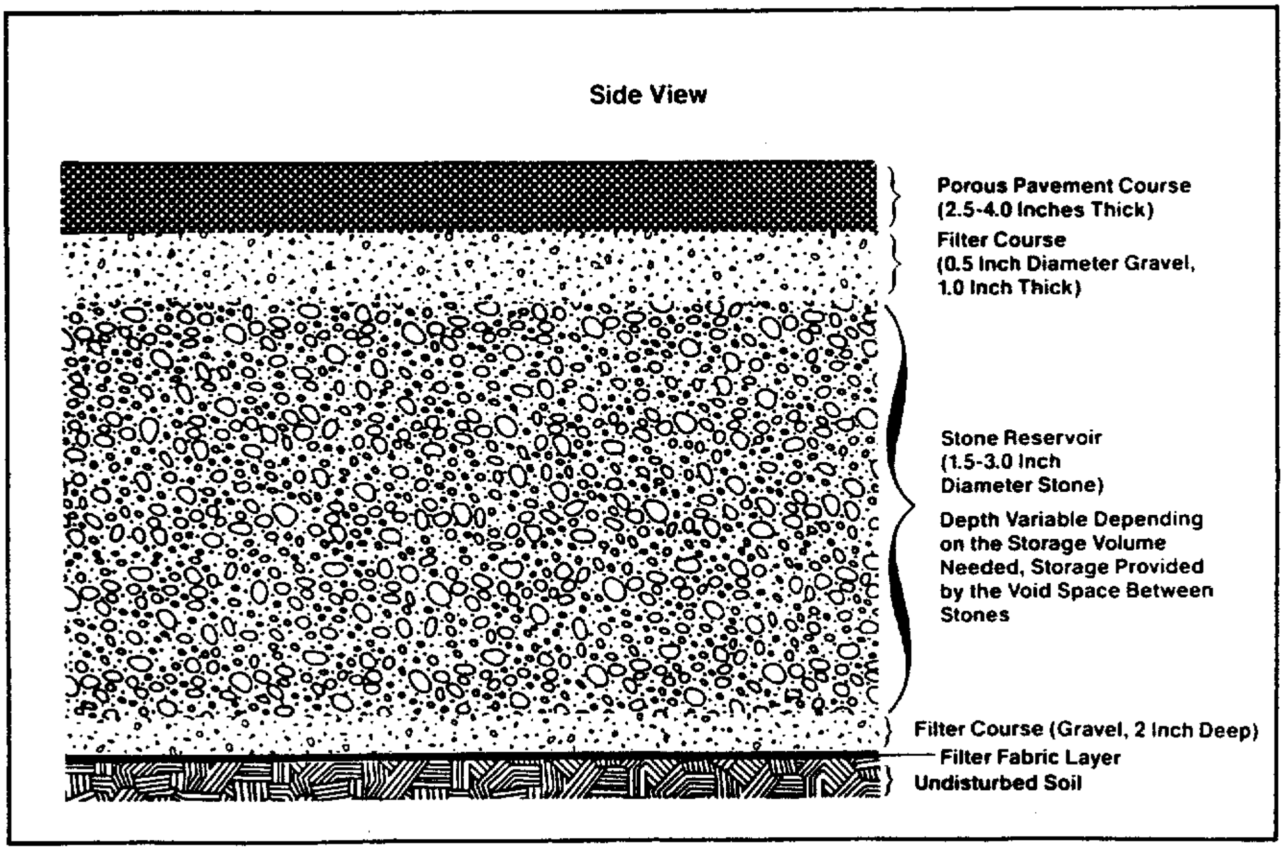
FIGURE 7-1. PLAN AND PROFILE OF A WETLAND POND

CHAPTER 7: POROUS PAVEMENT

Porous pavement has a high capability to remove both soluble and fine particulate pollutants in urban runoff, and also provides groundwater recharge, low flow augmentation, and streambank erosion control. Its use is generally restricted to low volume parking areas, although it can accept runoff from rooftop storage or adjacent conventionally paved areas. As a BMP, porous pavement is only feasible on sites with gentle slopes, permeable soils, and relatively deep water table and bedrock levels. When these conditions are met, porous pavement is a reasonably cost-effective BMP, particularly if off-site runoff contributions are not great.

When properly designed and carefully installed, porous pavement has load bearing strength, longevity, and maintenance requirements similar to conventional pavement. Some other advantages of porous pavement are reduced land consumption, reduction or elimination of the need for curb and gutters and downstream conveyance systems, the preservation of the natural water balance at the site, and a safer driving surface which offers better skid resistance and reduced hydroplaning.

Figure 7.1: Schematic of Typical Porous Pavement Section



Source: City of Rockville (1984a)

Sand Filter Design

Filtration systems must include both sedimentation and filtration components. The sedimentation component (or sedimentation chamber in this design) is an integral part of the overall filtration system because it:

- reduces the overall sedimentation load that reaches the filtration component; and
- ensures that the flow arrives at the sand filter as sheet flow, which prevents concentrated storm flow from scouring out sand.

The drainage area to the sand filter must be stabilized and should be no more than five acres. Larger drainage areas should be broken into smaller areas that drain to several sand filters to achieve site control. Enclosed storm drain systems will convey concentrated stormwater runoff. If any runoff is from pervious land areas, the sedimentation chamber must be enlarged to accommodate a wider range and volume of sediments.

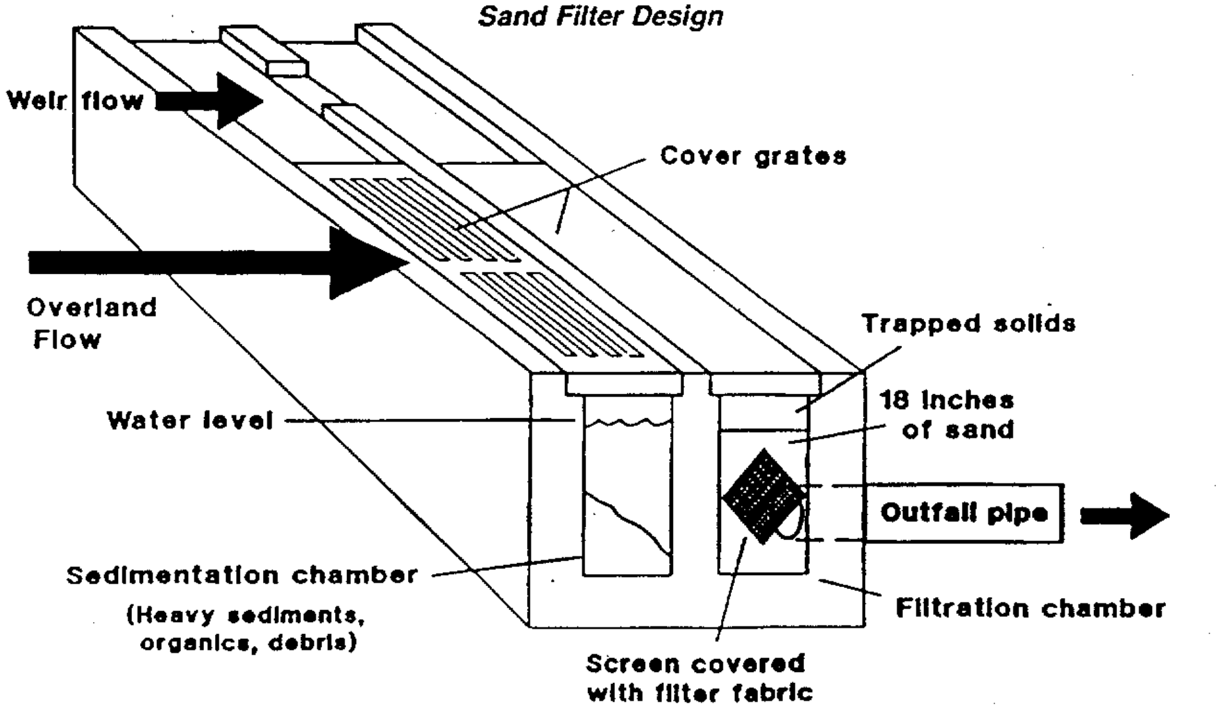
Most urban particulate matter is coarse like sand and gravel; however, most urban pollutants attach to fine particles such as silt and clay. One exception is toxic metals, which can attach to all sizes of soil particles. The sedimentation chamber primarily removes sand and gravel while the sand filter component will capture finer silt and clay particles.

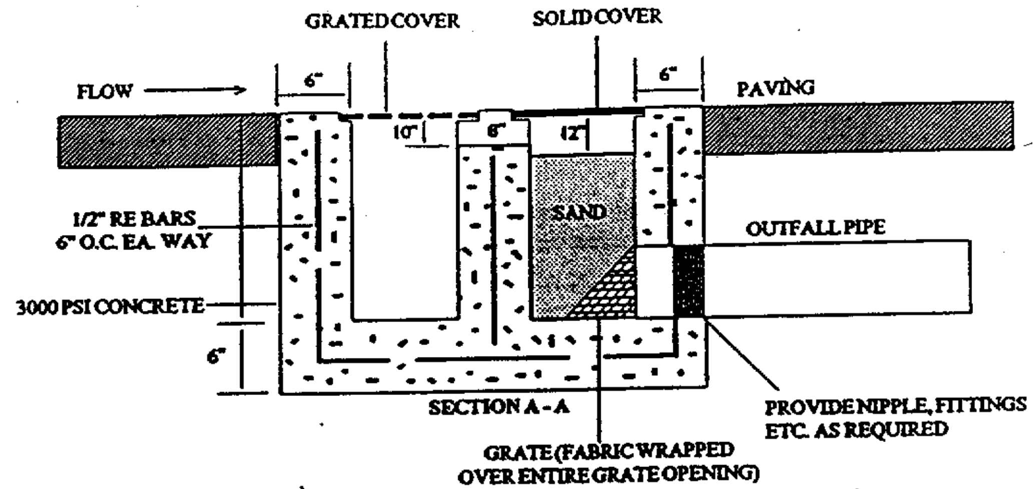
The sedimentation chamber should accommodate 540 cubic feet per storage acre for the entire area draining to the chamber. (This value is obtained by multiplying the surface area requirement by a depth of 18 inches.) The chamber's only outlet is through surface withdrawal, which creates dead storage that reduces resuspension of particulates deposited previously. In addition, surface withdrawal reduces the ability of heavier sediments to be conveyed from the sedimentation chamber into the filtration chamber because these heavy particles drop lower than the withdrawal point and become trapped in the sedimentation chamber.

Mosquitos will not become a problem as a result of standing water because:

- Water in the sedimentation chamber will generally have a sheen on its surface (from oils and greases contained in urban runoff) that smothers eggs and larvae; and
- Any eggs or larvae residing on the water's surface will be transported into the filtration chamber during the next runoff event. In addition, the chamber's materials dry out between storms, which eliminates moisture that mosquitos need.

Sand Filter Design





The sedimentation chamber primarily removes sand and gravel.

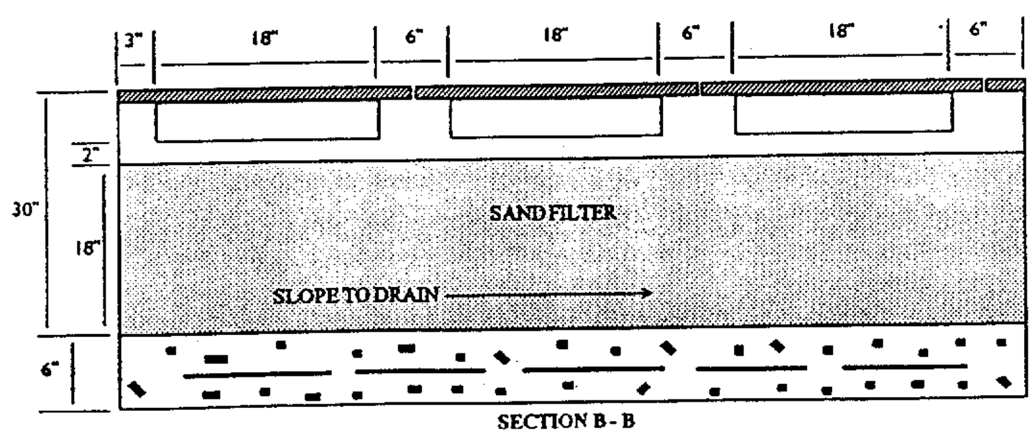
From a design standpoint, the sand filter component must be at least 18 inches deep. The system's surface area must be at least 720 square feet (per drainage acre) equally divided between the two chambers. The design relies on the following assumptions:

- the drainage area is less than five acres and totally impervious;
- the sedimentation chamber's volume is at least 540 cubic feet per storage acre;
- sand depth is at least 18 inches;
- volume of filtration chamber = volume of sedimentation chamber; and
- each chamber's surface area = 360 square feet per acre.

To create a minimum of 12 inches of sand over the pipe's top, the sand filter's outfall pipe must not exceed six inches in outside diameter. If the drainage area needs a larger conveyance system, several six-inch pipes should be used to create necessary flow. In addition, outfall pipe entrances must have grates covered with filter fabric to assure adequate flow and prevent sand from migrating out of the filtration chamber.

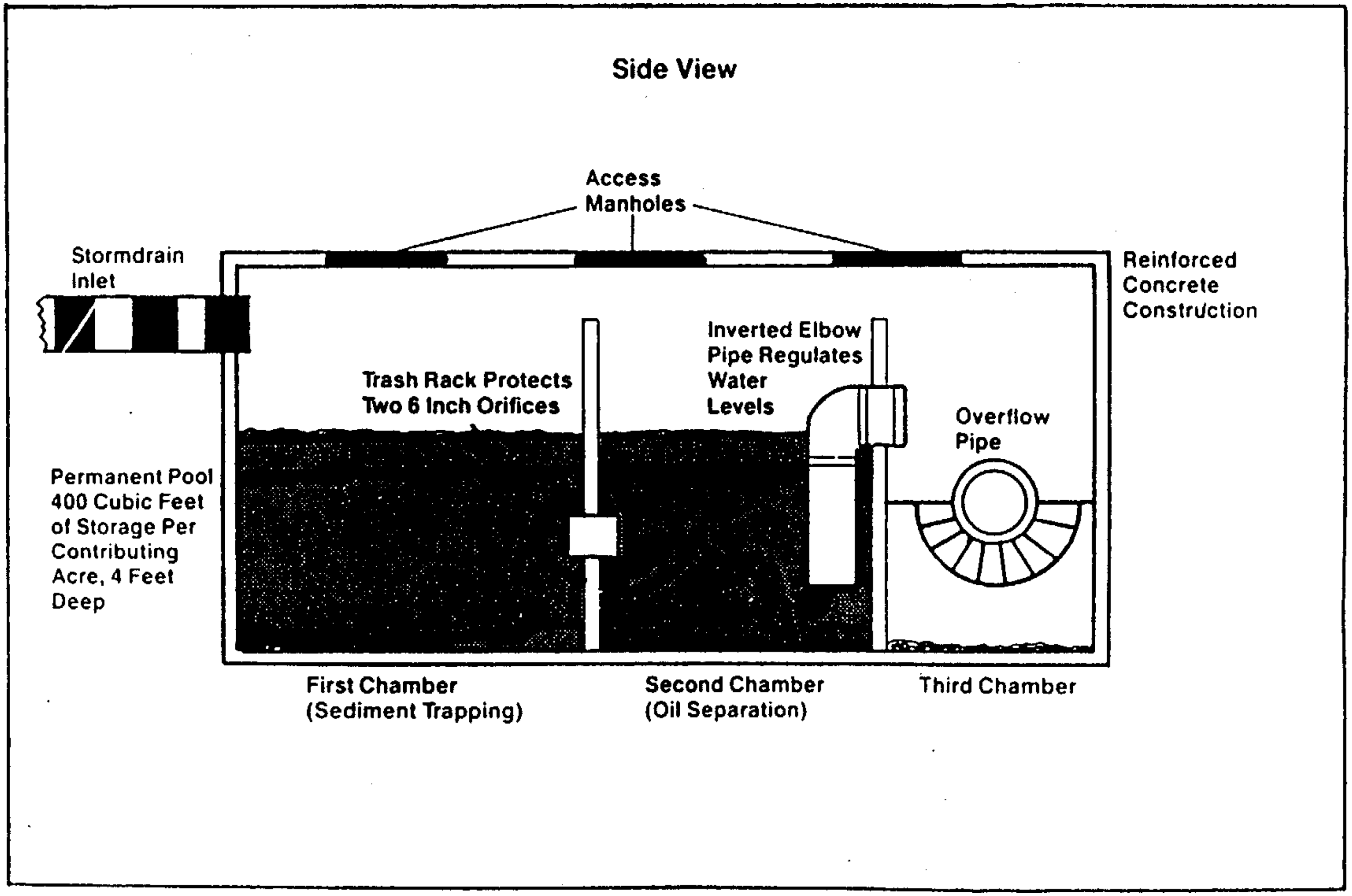
Large storms may overflow the sand filter system, creating excess runoff that remains untreated. However, because of the two-chamber design in conjunction with grate covers, particles should not be resuspended.

This design assumes that the sand filter is located on an urban parking area. If it was placed at the edge of a parking lot or street, the system would not be designed for the same structural load. In these situations, the structural design may be reduced, but the sand filter's surface area and volume requirements must be maintained.



The sedimentation chamber has no outlet other than through surface withdrawal.

Figure 8.1: Schematic of a Water Quality Inlet, Montgomery County, MD. Three Chamber Design



SCHUELER, 1987

Pamphlets can be inserted into utility bills to help educate citizens about stormwater management. Informative materials have been developed by the Department, water management districts and local governments to help educate the public. Slide shows and other technical assistance is available from the Department and the water management districts.

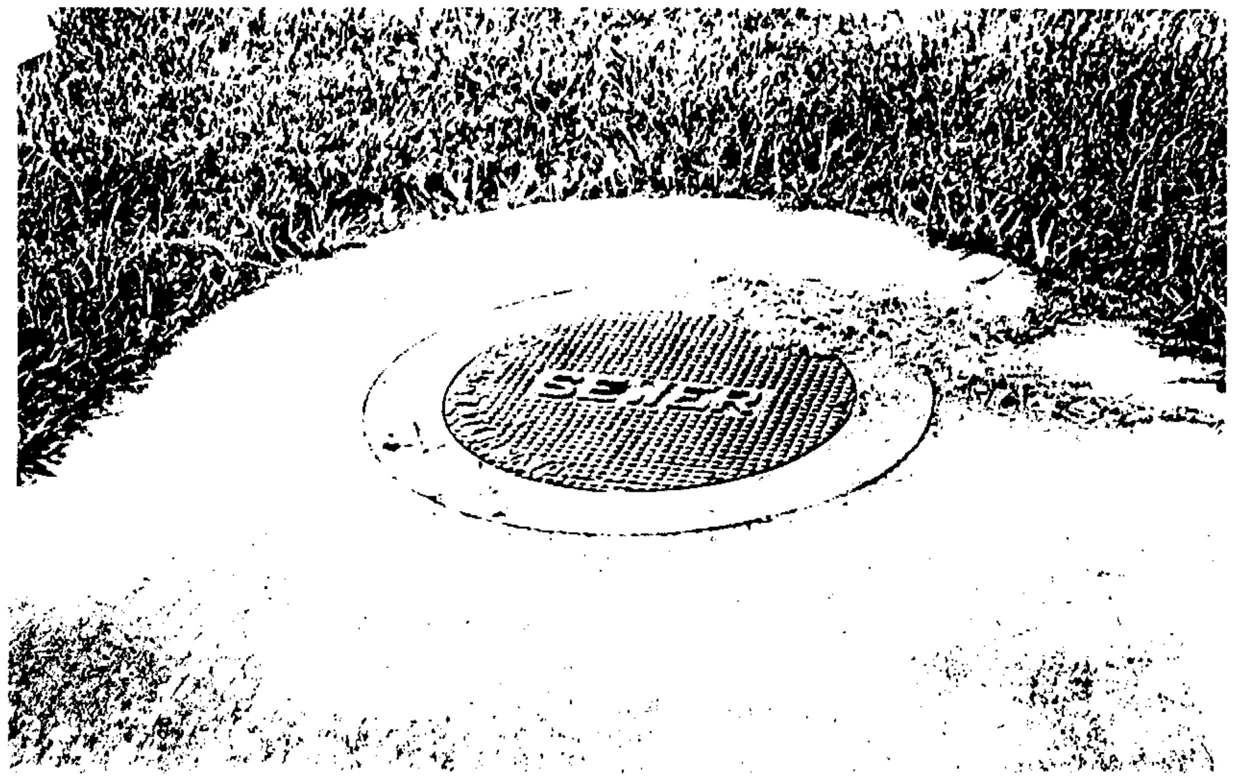


Table 9.1—Annual pollutant loads (in pounds).

	EXISTING SITE CONDITIONS	OUTPUTS AFTER MANAGEMENT	TOTAL REDUCTIONS
Total P	84	63	21
PO_4	48	33	15
Total N	610	478	132
NO_3	177	136	41
TKN	433	361	62
COD	16,737	12,896	3,841
BOD	2,193	1,712	481
Zinc	32	23	9
Lead	33	23	9
Copper	8	6	2

Source: Chris Athanas, Ph.D. & Assoc. 1992.

priority. Individual outfalls and the areas draining to them were considered for additional runoff management. One area that had consolidated four original outfall points is being treated by a constructed wetland to ensure reduced pollutant discharge. Management controls have been designed for other outfall points in case monitoring requires additional controls. While these practices may never be needed, the owner has set aside areas for possible use as vegetated swales, infiltration trenches, or sand filter systems.

The master plan development cost $42,000, including detailed design plans for the constructed wetland.

Recommended Reading

References Cited

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Washington Department of Ecology. 1992. Stormwater Management Manual for the Puget Sound Basin. Olympia, WA.

For NPDES guidance documents, contact Permits Division (see Appendix C).

"Horner et. al., 1994"

EROSION PREVENTION AND SEDIMENT CONTROL

EROSION PREVENTION AND SEDIMENT CONTROL

Erosion prevention reduces the amount of sediment generated from the land. Once erosion occurs, sediment control practices are necessary to limit the downstream movement of the sediment.

"Horner et. al., 1994"

I. EROSION PREVENTION

Once an area has been disturbed, the single most important erosion control practice is stabilization with the intended ground cover.

"Horner et. al., 1994"

II. SEDIMENT CONTROL

A. Generally, sheet flow will exit from a maximum slope length of about 100 feet (30.48 m). Once flow exceeds that length, areas of concentrated flow form small rivulets and channels.

B. Controls consist of two elements: a means to convey or divert runoff such as diversion berms or swales, and the actual trapping practice.

"Horner et. al., 1994"

III. HISTORICAL PROBLEM AREAS

A. While most states have sediment control laws, most laws are ineffective, weak, or for the most part ignored. An effective program requires laws that are equitable and consistently applied throughout a jurisdiction. Programs not having well-defined criteria and review and inspection procedures will not be successful. A major problem, unique to erosion and sediment control, is that control practices are temporary.

"Horner et. al., 1994"

B. Therefore, the driving mechanism for an effective erosion and sediment control program is a clearly defined uniform law defining responsibilities and enforcement options. The law should mandate the review and approval requirements before site clearing and enforcement options if control measures are inadequate.

"Horner et. al., 1994"

- Local agencies should require a plan review before construction begins.

- The average plan reviewer can review two to six plans a day, depending on the plan's complexity.

- The reviewer can expect over 50 percent of the original submissions to be incomplete or contain errors in the site control approach.

- Time limits should be set for previously approved projects to be resubmitted for approval.

"Horner et. al., 1994"

E. Plans should include adequate legal authorization to stop work and apply penalties if necessary.

"Horner et. al., 1994"

IV. EDUCATION

Delaware and Maryland require contractors to send a representative to a certification program. The three-and-a-half hour program educates contractors on the need for runoff management and their responsibilities under the program. As of 1987, Maryland has certified over 10,000 individuals. Since Delaware's program began in 1991, over 2,000 individuals have been certified. These programs continue to be popular with contractors.

"Horner et. al., 1994"

V. STAFFING

Relying on building plan reviewers and building inspectors to implement the program reduces the program's effectiveness. Delaware has implemented an innovative approach to inspection and enforcement through its Certified Construction Reviewer (CCR) program.

The developer provides a CCR to inspect the site weekly and submit an inspection form to the developer, contractor, and the responsible inspection agency. To qualify, the CCR attends a 32-hour training course that covers such topics as water quantity and quality, soils, vegetation, site inspection procedures, and laws and regulations.

"Horner et. al., 1994"

Upon passing a final examination, the individual receives certification. The CCR must submit accurate, weekly reports but is not required to initiate enforcement action. The public agency must still conduct periodic inspections and initiate enforcement, but the CCR program represents a means to reduce public inspection requirements.

"Horner et. al., 1994"

SAND FILTERS

Total suspended solids	75 to 87%
Total phosphorus	19 to 61%
Total nitrogen	31 to 44%
Nitrate + nitrite-nitrogen	-79 to -5%
Lead	71 to 88%
Zinc	49 to 82%
Copper	33 to 60%
Chemical oxygen demand	45 to 68%

"Horner et. al., 1994"

POLLUTION PREVENTION PLAN

1. Reduction of pollutants at the source.

   - Vehicle or equipment fueling areas
   - Painting operations
   - Loading and unloading areas
   - Salt storage facilities

"Horner et. al., 1994"

2. Recycling

- Spent solvents
- Paint thinner
- Degreasers
- Used oil/oil filters

"Horner et. al., 1994"

3. Treatment of runoff.

- Detention basins -- extended detention both dry and wet

- Infiltration practices -- use caution to prevent groundwater contamination

- Filtration practices

"Horner et. al., 1994"

4. Disposal through approved method.

"Horner et. al., 1994"